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Muroi et al.

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(54) **METHOD AND DEVICE FOR TREATING WASTE LIQUID, SOLVENT SEPARATOR, AND CLEANING DEVICE USING THEREOF**

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(52) **U.S. Cl.** **210/748**; 210/806; 210/167; 210/188; 210/295; 210/908
(58) **Field of Search** 210/748, 806, 210/167, 188, 295, 908

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(57) **ABSTRACT**

A solvent separator includes an introduction member which introduces a mixture including chlorine containing organic solvent and water; a separation unit including a separation member made of a water-repellent and/or lipophilic porous material, which carries out the separation of the mixture; a water drainage member through which water separated by the separation unit is discharged; and a solvent drainage member through which the chlorine containing organic solvent separated by the separation unit is discharged. Also, a method and a device for treating waste liquid are provided by which chlorine containing organic solvent present in waste liquid is selectively separated, decomposed by a photocatalyst, and converted into a harmless substrate.

14 Claims, 10 Drawing Sheets

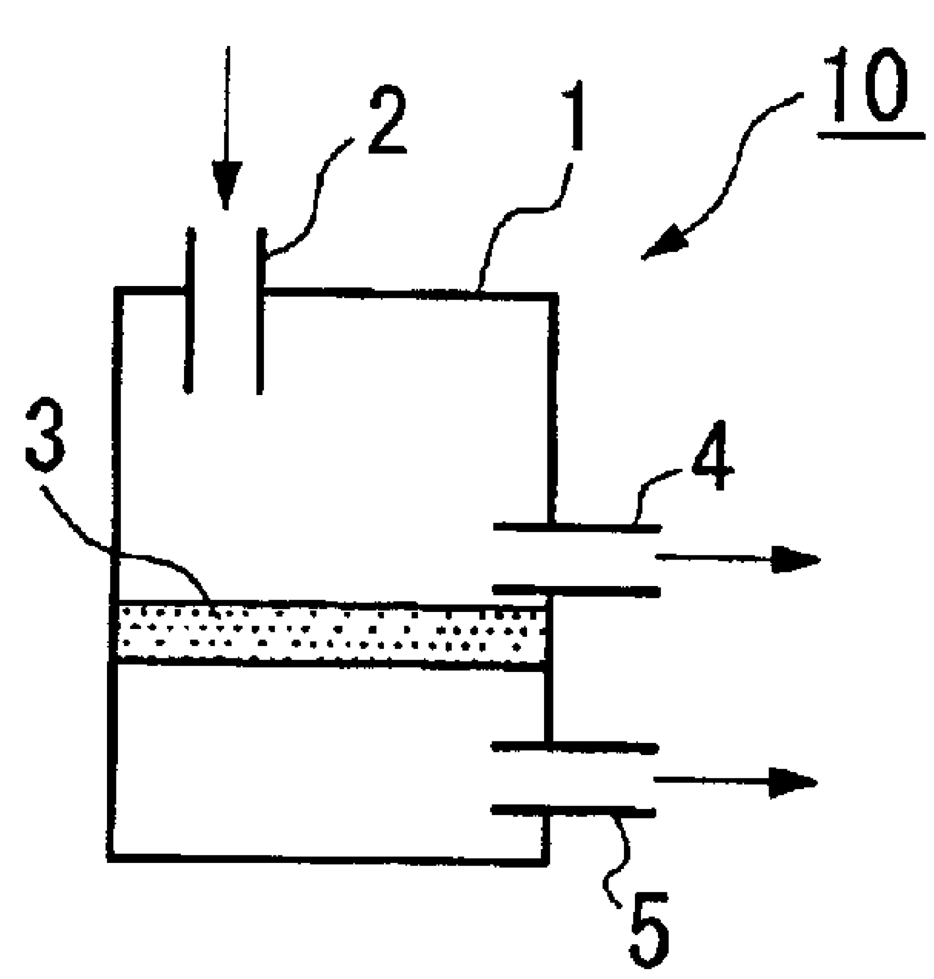

FIG. 1A

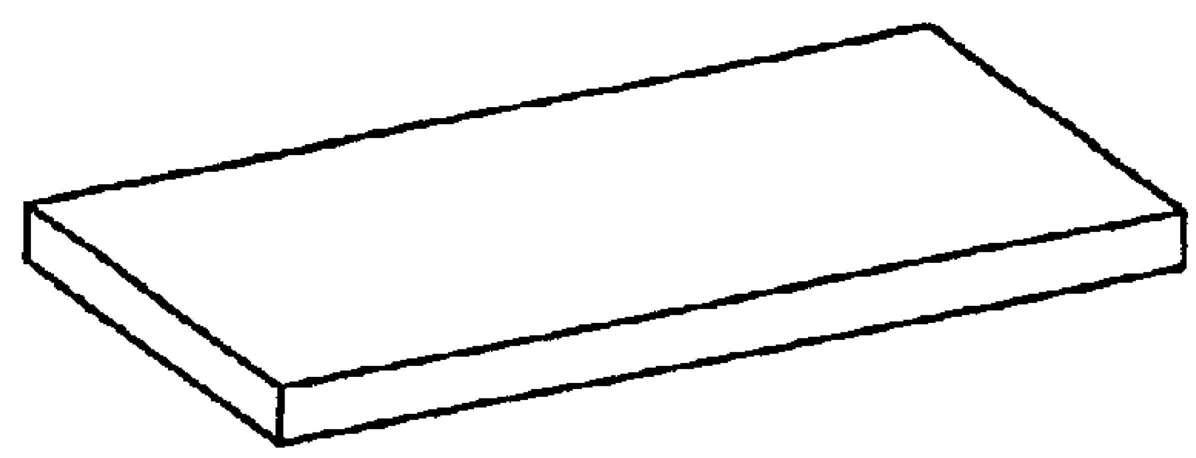

FIG. 1B

FIG. 1C

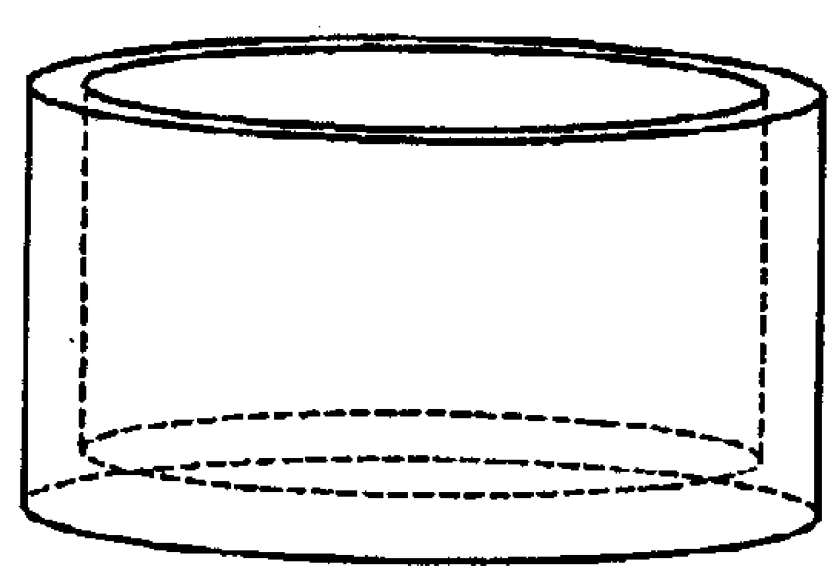

FIG. 1D

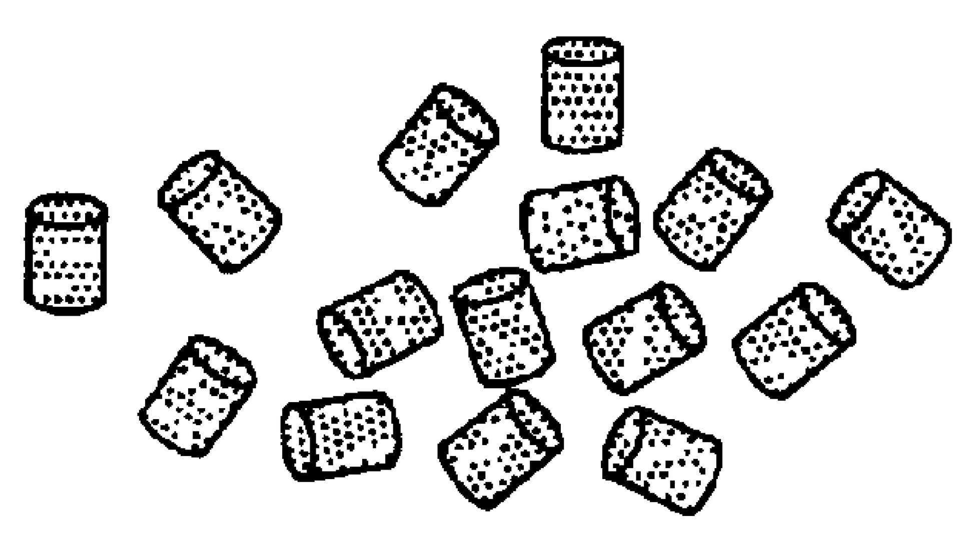

FIG. 2

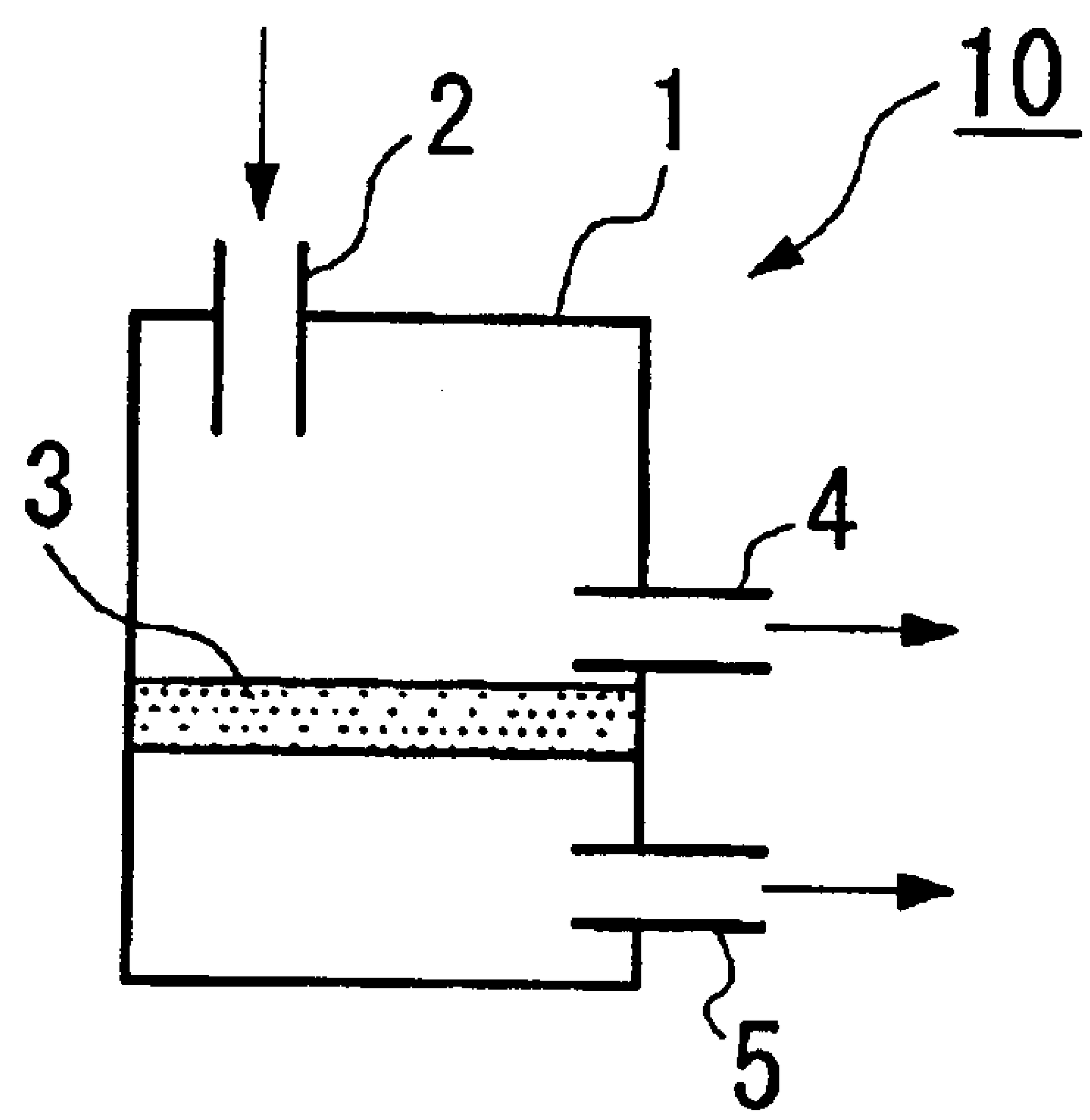

FIG. 3

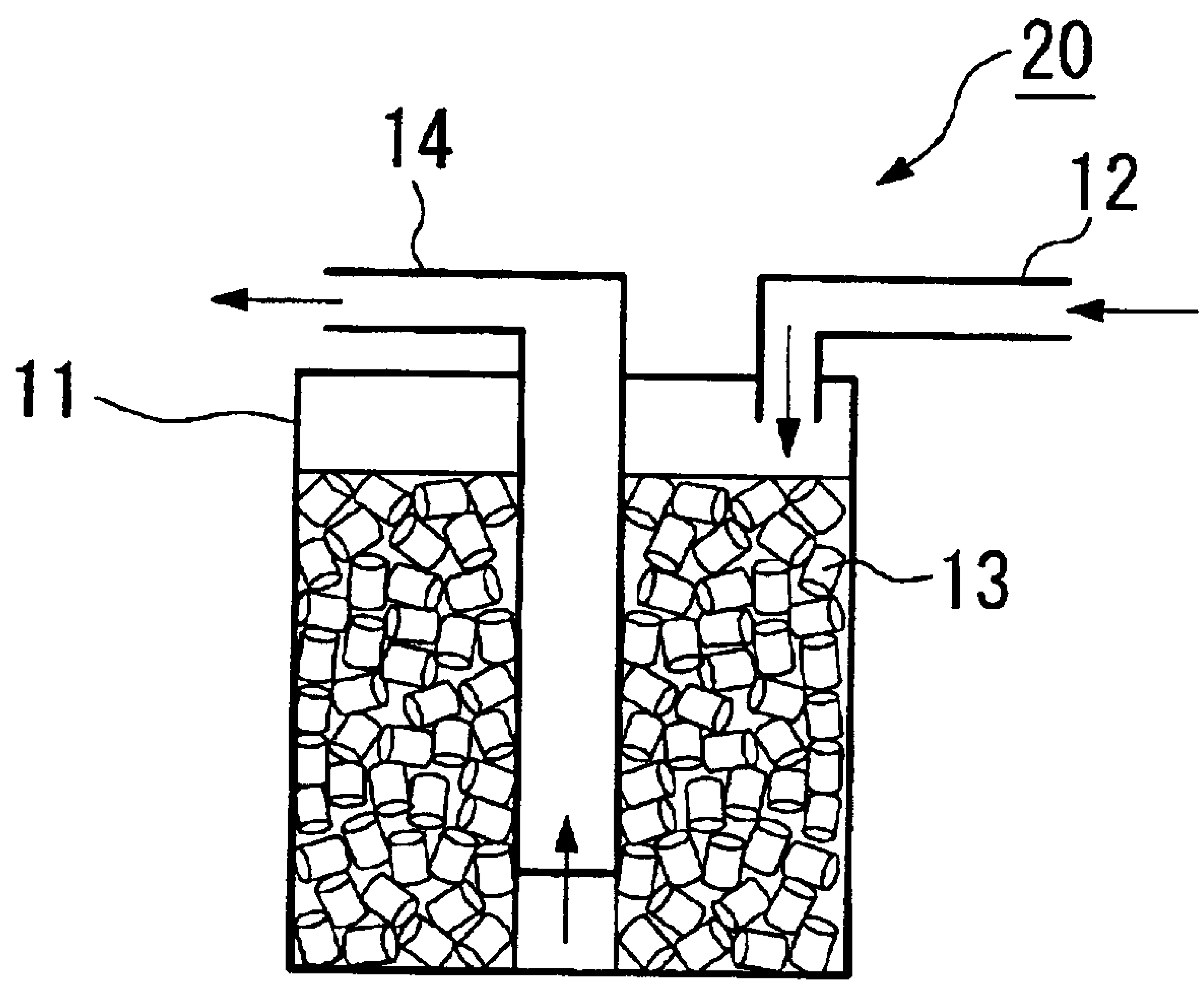

FIG. 4A

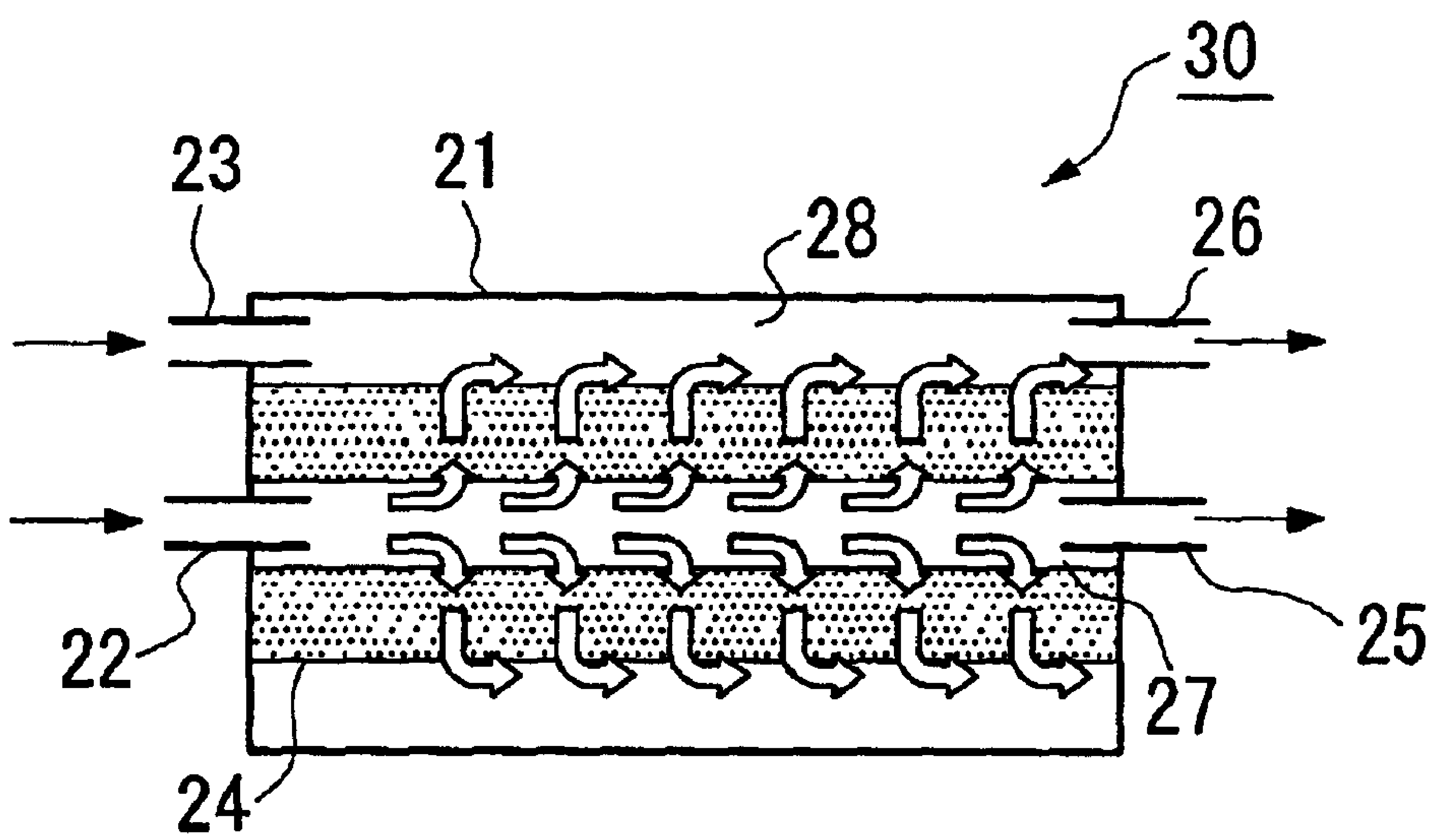

FIG. 4B

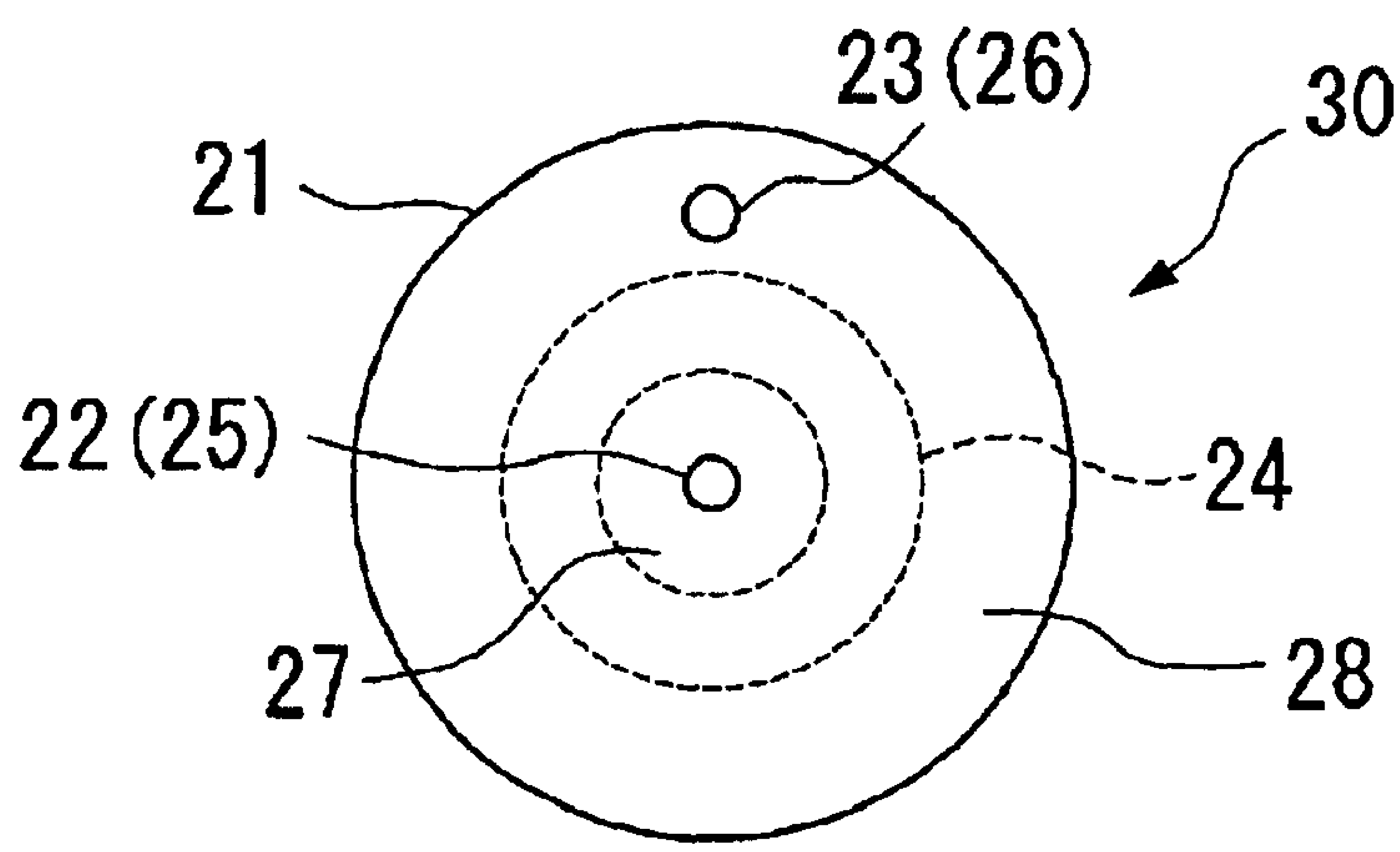

FIG. 5

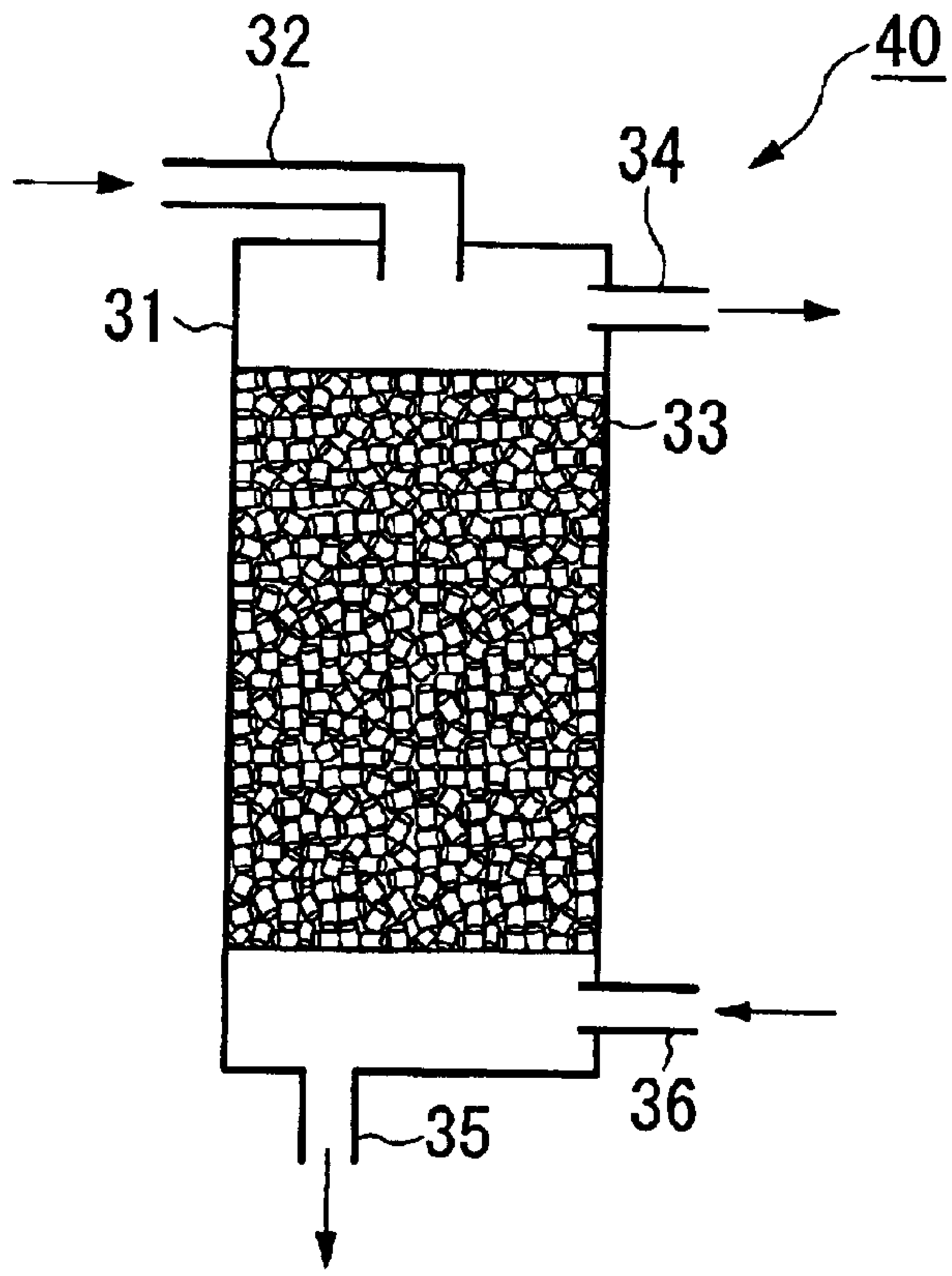

FIG. 6

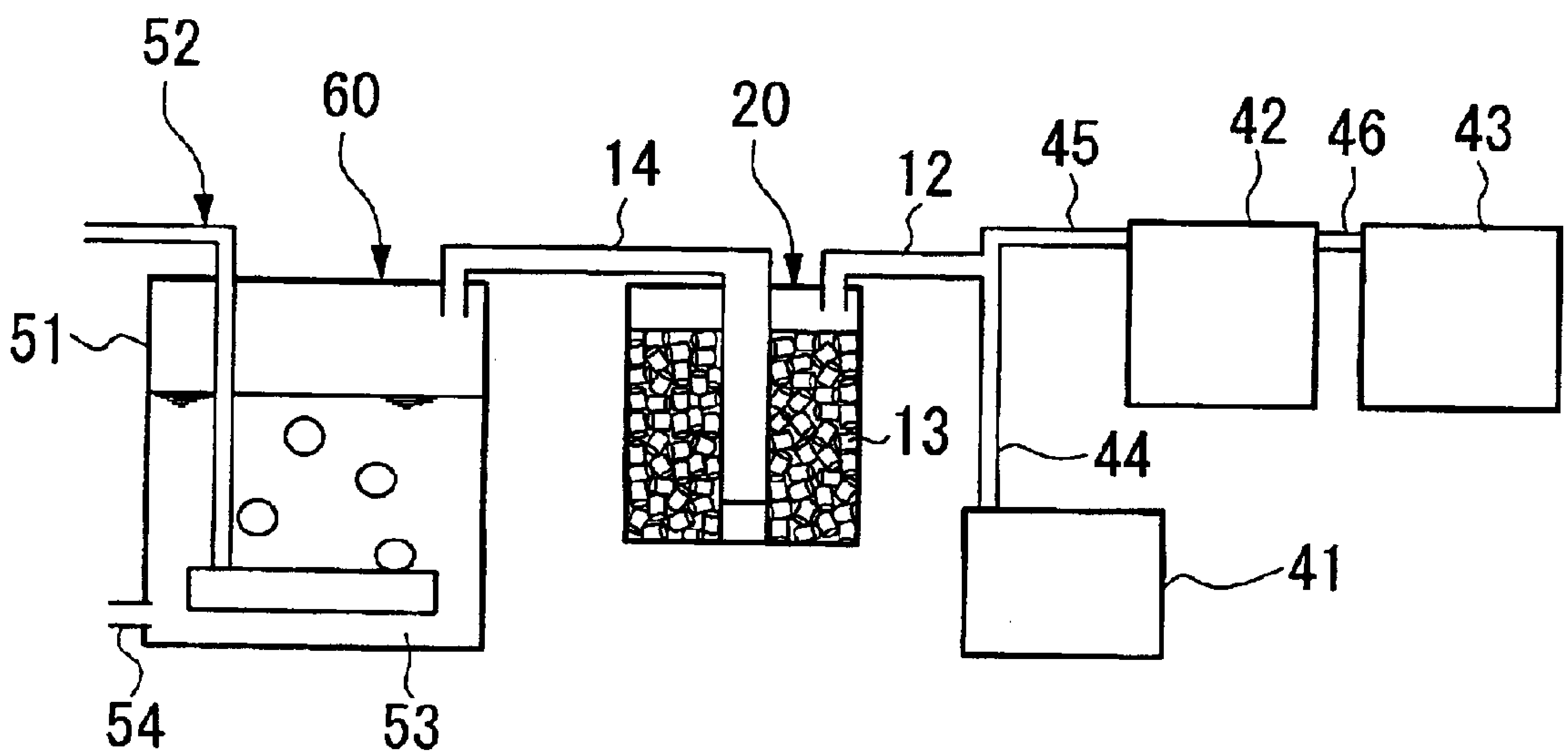

FIG. 7

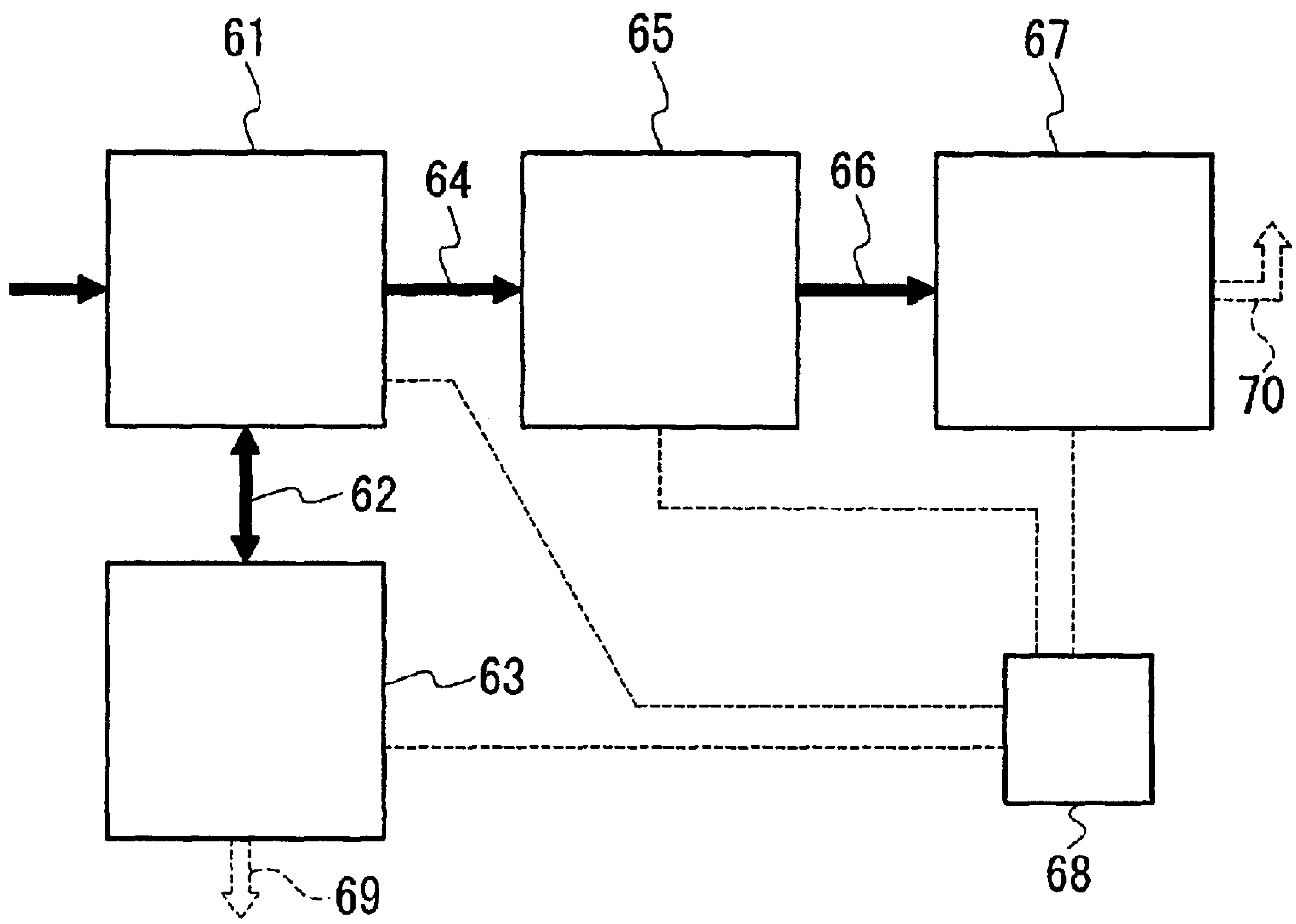

FIG. 8

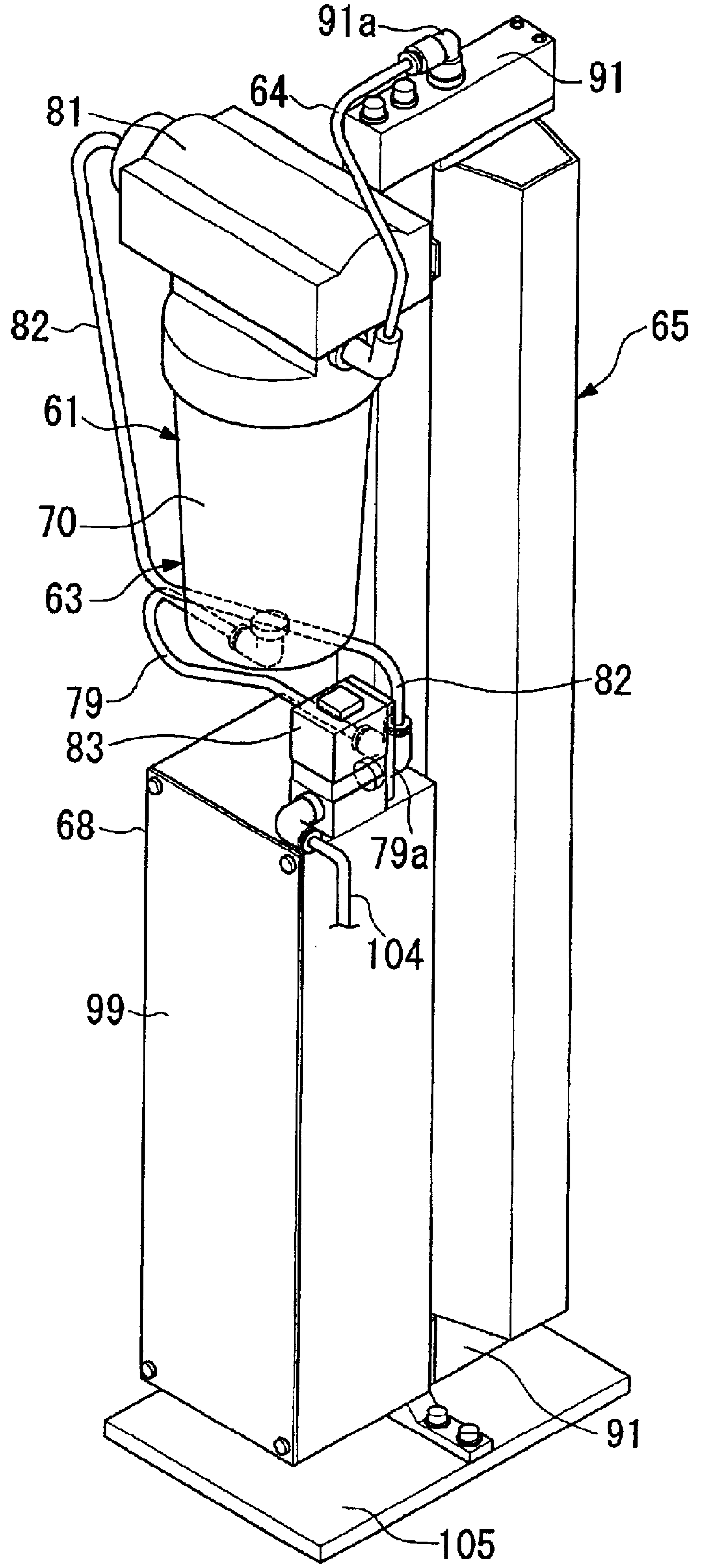

FIG. 9

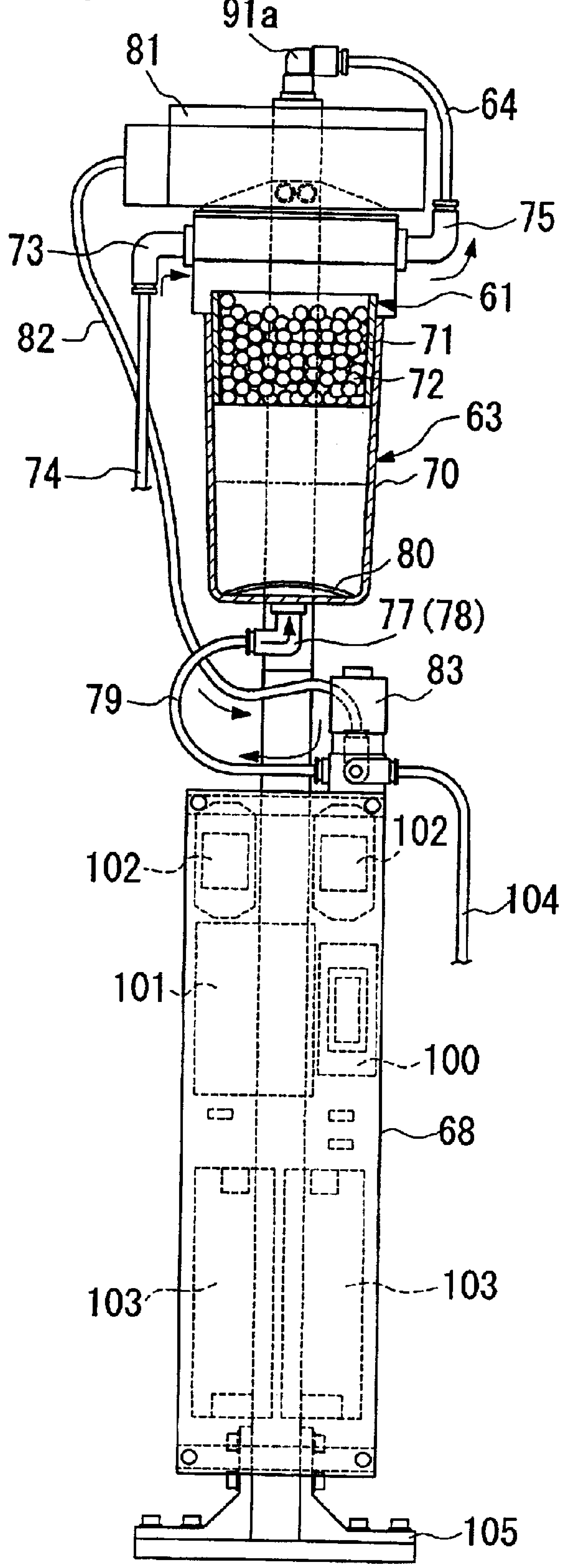
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FIG. 10

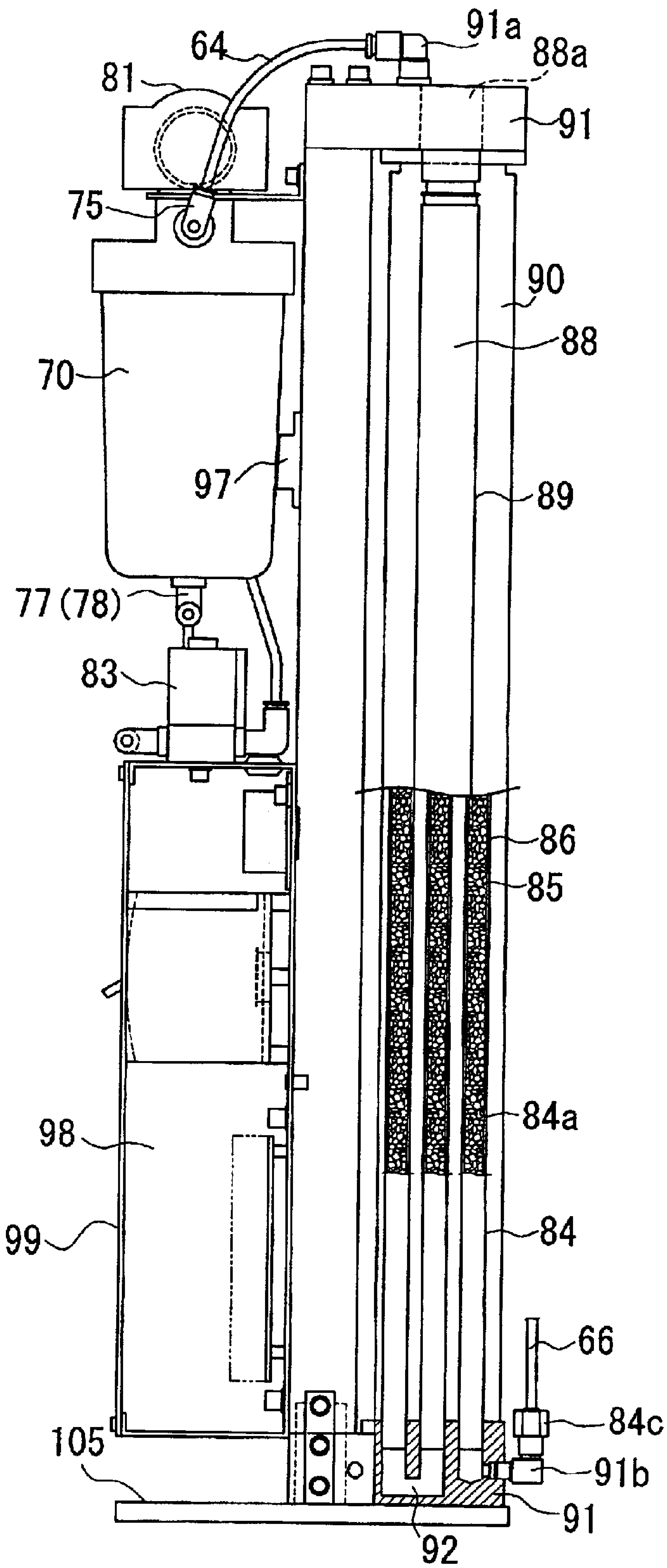
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FIG. 11

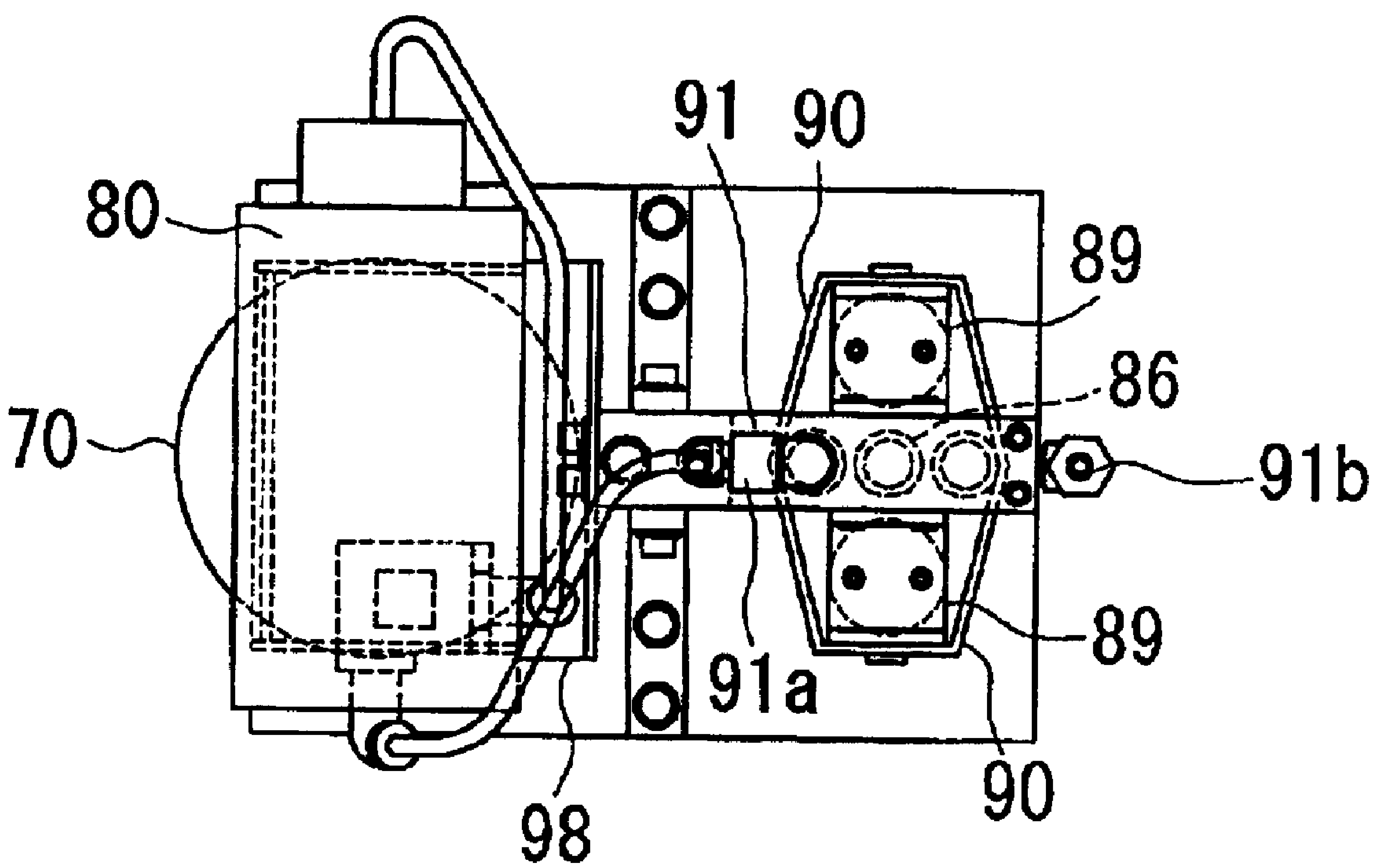
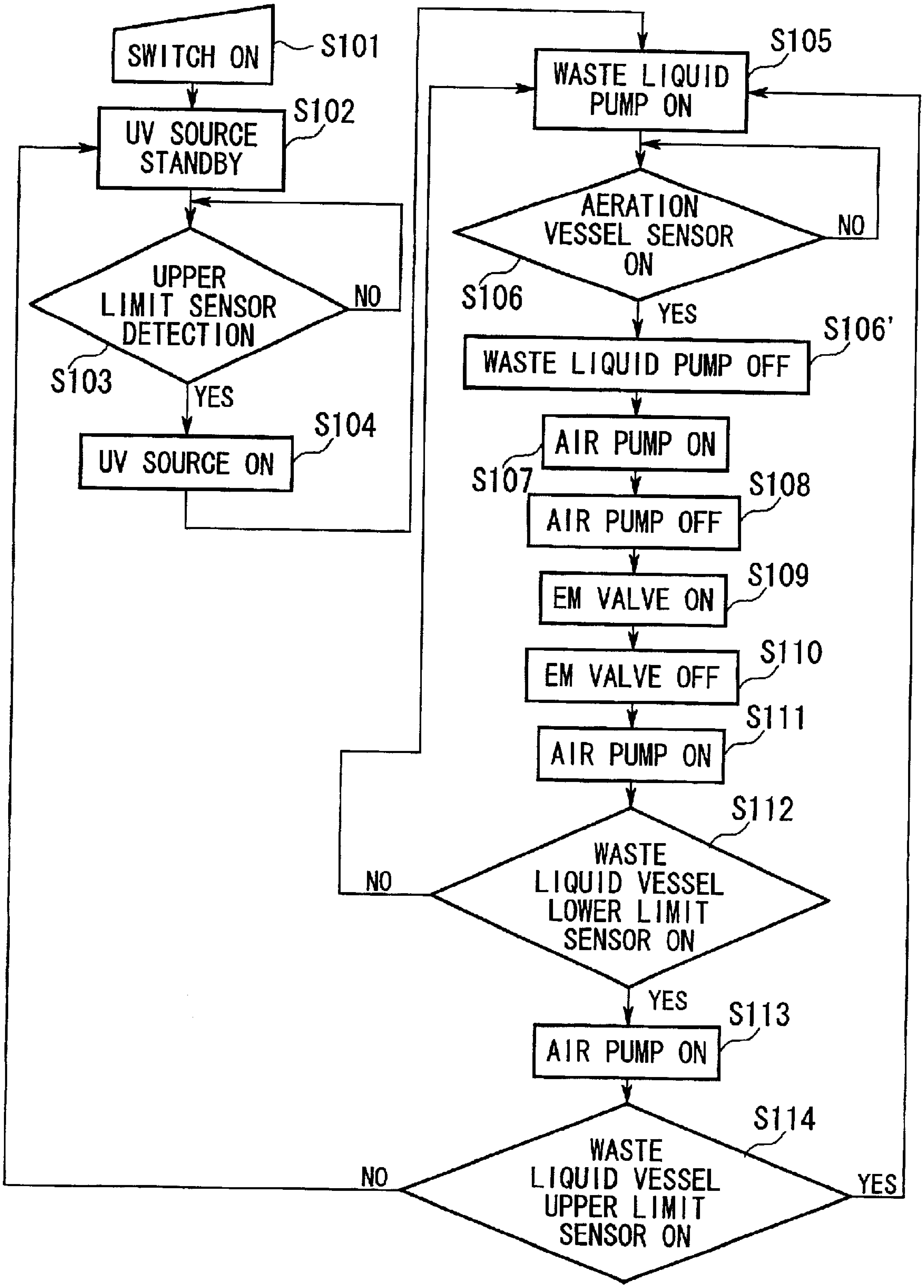


FIG. 12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S102
UPPER LIMIT SENSOR DETECTION
S103
NO
YES
UV SOURCE ON
S104
WASTE LIQUID PUMP ON
S105
AERATION VESSEL SENSOR ON
S106
NO
YES
WASTE LIQUID PUMP OFF
S106'
AIR PUMP ON
S107
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S108
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S109
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S110
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S111
WASTE LIQUID VESSEL LOWER LIMIT SENSOR ON
S112
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S113
WASTE LIQUID VESSEL UPPER LIMIT SENSOR ON
S114
NO
YES

METHOD AND DEVICE FOR TREATING WASTE LIQUID, SOLVENT SEPARATOR, AND CLEANING DEVICE USING THEREOF

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method and a device for treating waste liquid, solvent separator and a cleaning or a dry cleaning device using the device or the separator. More specifically, the present invention relates to a method and a device for treating a waste liquid by which a chlorine containing organic solvent present in the exhaust gas or waste liquid generated during a process using a chlorine containing organic solvent, such as trichloroethylene used in a metal part washing device, or tetrachloroethylene used in a dry cleaning device, is selectively separated, decomposed by a photocatalyst, and made harmless. The present invention also relates to a solvent separator which may be used for selectively separating/collecting an organic solvent containing chlorine from a waste liquid, and a cleaning or a dry cleaning device using such a device or solvent separator. The solvent separator of the invention possesses an excellent processing efficiency.

2. Description of Related Art

Chlorine containing organic solvents have been widely used because they are excellent cleaning agents due to their superior cleaning properties, stability, and non-flammability.

Recently, since the chlorine containing organic solvents are considered to be hazardous air pollutants and designated as the priority controlled substances, self-regulated substances, etc., in air pollution control laws, various attempts have been made, such as one utilizing an adsorption method using activated carbon or a heat vaporization treatment method, to decrease the amount of chlorine containing organic solvents contained in the waste liquid or exhaust gas discharged from cleaning devices, such as dry cleaning devices, to within the emission standard value (for example, 0.1 mg/L of tetrachloroethylene in Japan) defined in the Water Pollution Control Law.

In an adsorption method using activated carbon, it is necessary to replace the activated carbon when the adsorption capacity of the activated carbon is saturated. However, it is difficult to determine when the activated carbon has lost its adsorption capacity. Also, it is necessary for the user to dispose of the adsorption-saturated activated carbon as designated waste, or to recycle it after subjecting it to a desorption-regeneration process using water vapor. Accordingly, the use of activated carbon is inefficient and gives rise to extra costs.

On the other hand, by using a heat vaporization treatment method, the concentration of chlorine containing organic compounds in waste liquid can be decreased to within emission standard values by vaporizing the waste liquid.

However, according to this method, there is the problem that the treatment efficiency is decreased when the concentration of the chlorine containing organic compounds in waste liquid is low. Also, since the vaporized chlorine containing organic compounds are emitted to the air without being decomposed, there is a problem that the amount of chlorine containing organic compounds in the exhaust gas discharged in the environment cannot be substantially controlled.

Also, since regulations relating to the emission of chlorine containing organic compounds have been made increasingly stringent, there is demand for a method and a device for treating waste liquid having an excellent decomposition efficiency.

In addition, since water is usually contained in the waste liquid discharged from a cleaning device, such as a dry cleaning device, it is necessary to separate the water from the waste liquid in order to collect the chlorine containing organic solvent. Conventionally, methods in which the difference in specific gravity between a chlorine containing organic solvent and water is utilized to separate the chlorine containing organic solvent from water have been generally employed. When aqueous waste liquid containing water and a chlorine containing organic solvent is left to stand in a container, water and the solvent are separated in two layers and the chlorine containing organic solvent whose specific gravity is larger than water constitutes the lower layer. The chlorine containing organic solvent present in the lower layer is discharged and separated from the water.

However, if the chlorine containing organic solvent is dispersed and present in waste liquid in a fine particle state, it is difficult to achieve perfect separation of the solvent and some of the solvent remains in the water. Also, if the waste liquid is collected and addition and discharge of the waste liquid are carried out repeatedly in a recovery container, the chlorine containing organic solvent and water, which have been separated in two layers, are again mixed and dispersed, and then discharged in the dispersed state. Accordingly, by using a conventional separation method which utilizes the difference in specific gravity between a chlorine containing organic solvent and water, it is not possible, or at least difficult, to decrease the concentration of chlorine containing organic compounds in the waste liquid to a level satisfying the above-mentioned emission standards.

Moreover, since the laws for regulating discharge of the above-mentioned chlorine containing organic compounds are becoming increasingly stringent, there is a demand for a method and a device for treating waste liquid having a better separation efficiency have been awaited.

SUMMARY OF THE INVENTION

The present invention takes into consideration the above-mentioned circumstances, and has an object of providing a method for treating waste liquid in which a solvent separation process is incorporated in a series of processes for decomposing chlorine containing organic solvent present in waste liquid so that the treatment efficiency is improved and the emission of secondary by-products such as chlorine gas is decreased. The present invention also provides a device which is used for the above-mentioned method, and a cleaning or a dry cleaning device using the device for treating waste liquid, which are capable of automating the above-mentioned series of processes. In addition, the present invention provides a solvent separation device capable of selectively separating and collecting chlorine containing organic solvents, especially, finely dispersed chlorine containing organic solvents, contained in waste liquid with excellent processing efficiency.

The above objects may be achieved by a solvent separator including: an introduction member which introduces a mixture comprising chlorine containing organic solvent and water; a separation unit comprising a separation member made of a water-repellent and/or lipophilic porous material, which carries out the separation of the mixture; a water drainage member through which water separated by the separation unit is discharged; and a solvent drainage member through which the chlorine containing organic solvent separated by the separation unit is discharged.

The present invention also provides a solvent separator including: an introduction member which introduces a mixture comprising chlorine containing organic solvent and water; a separation unit comprising a separation member made of a water-repellent and/or lipophilic porous material, which carries out the separation of the mixture; a water drainage member through which water separated by the separation unit is discharged; a supply member which supplies air to the separation unit to vaporize the chlorine containing organic solvent; and an exhaust member through which the air supplied by the supply member and/or vaporized chlorine containing organic solvent is discharged.

In accordance with another aspect of the invention, the shape of the separation member is a film, plate, tube, container, or granules.

The present invention also provides a dry cleaning device including the above-mentioned solvent separator.

The above objects may also be achieved by a method for treating waste liquid including the steps of: carrying out a solvent separation process in which chlorine containing organic solvent present in the waste liquid is separated; carrying out a vaporization treatment process in which a part of the chlorine containing organic solvent remains in the waste liquid after the solvent separation process is vaporized; carrying out a photooxidation-decomposition process in which gases vaporized from the waste liquid are subjected to a photooxidation-decomposition treatment; and carrying out an after-treatment process in which decomposition product gases produced by the photooxidation-decomposition treatment are converted into a harmless substrate.

In accordance with another aspect of the invention, the decomposition product gases are adsorbed, and/or absorbed, and neutralized in the after-treatment process to be converted into a harmless substrate.

In yet another aspect of the invention, the solvent separation process is performed prior to the vaporization treatment process.

In yet another aspect of the invention, the waste liquid is made to contact a separation member made of a water-repellent and/or lipophilic porous member so that the chlorine containing organic solvent present in the waste liquid is adsorbed by the separation member in the solvent separation process.

In yet another aspect of the invention, the vaporization treatment process is performed by using an aeration method.

In yet another aspect of the invention, the vaporization treatment process further includes a step of vaporizing the chlorine containing organic solvent adsorbed by the separation member.

The above objects may also be achieved by a waste liquid treatment device, including: a solvent separation unit which separates chlorine containing organic solvent present in waste liquid; a vaporization treatment unit which vaporizes a part of the chlorine containing organic solvent which is not separated by the solvent separation unit and remains in the waste liquid; a photooxidation decomposition processing unit which photooxidizes and decomposes gases vaporized from the waste liquid by the vaporization treatment unit; an after-treatment unit which converts decomposition product gases produced by the photooxidation-decomposition processing unit into a harmless matter; and a control unit including a sequencer which controls an operation of the solvent separation unit, the vaporization treatment unit, the photooxidation decomposition processing unit, and the after-treatment unit.

In accordance with another aspect of the invention, the after-treatment unit adsorbs, and/or absorbs, and/or neutralizes the decomposition product gases in order to convert the decomposition product gases into a harmless substance.

The present invention also provides a cleaning device including the above-mentioned waste liquid treatment device.

The present invention also provides a dry cleaning device including the above-mentioned waste liquid treatment device.

BRIEF DESCRIPTION OF THE DRAWINGS

Some of the features and advantages of the invention having been described, others will become apparent from the detailed description which follows, and from the accompanying drawings, in which:

FIGS. **1**A through **1**D are schematic diagrams showing separation units made of a porous material which may be used in embodiments of the present invention;

FIG. **2** is a diagram showing a cross-sectional view of a solvent separator according to an embodiment of the present invention;

FIG. **3** is a diagram showing a cross-sectional view of a solvent separator according to another embodiment of the present invention;

FIG. **4**A is a diagram showing a cross-sectional view of a solvent separator according to yet another embodiment of the present invention, and FIG. **4**B is a diagram showing a side view of the solvent separator shown in FIG. **4**A;

FIG. **5** is a diagram showing a cross-sectional view of a solvent separator according to yet another embodiment of the present invention;

FIG. **6** is a diagram showing a waste liquid processing device of a dry cleaning device in which the solvent separator according to an embodiment of the present invention is employed;

FIG. **7** is a schematic diagram for explaining a waste liquid treatment device according to an embodiment of the present invention;

FIG. **8** is a diagram showing a schematic perspective view of a waste liquid treatment device according to another embodiment of the present invention;

FIG. **9** is a diagram showing a schematic elevational view of the waste liquid treatment device shown in FIG. **8**, some parts of which are shown in perspective;

FIG. **10** is a diagram showing the side view of the waste liquid treatment device shown in FIG. **8**, some parts of which are shown in perspective and in cross-sectional;

FIG. **11** is a diagram showing a schematic plan view of the waste liquid treatment device shown in FIG. **8**, some parts of which are shown in perspective; and

FIG. **12** is a flowchart for explaining the operation of the waste liquid treatment device according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention summarized above and defined by the enumerated claims may be better understood by referring to the following detailed description, which should be read with reference to the accompanying drawings. This detailed description of particular preferred embodiments, set out below to enable one to build and use particular implementations of the invention, is not intended to limit the enumerated claims, but to serve as particular examples of the invention.

The solvent separator according to an embodiment of the present invention includes, as mentioned above, an introduction member which introduces a mixture including a chlorine containing organic solvent and water; a separation unit including a separation member made of a water-repellent and/or lipophilic porous material, which carries out the separation of the mixture; a water drainage member through which the water separated by the separation unit is discharged; and a solvent drainage member through which the chlorine containing organic solvent separated by the separation unit is discharged. Further, the solvent separator according to another embodiment of the present invention includes an introduction member which introduces a mixture including a chlorine containing organic solvent and water; a separation unit including a separation member made of a water-repellent and/or lipophilic porous material, which carries out the separation of the mixture; a water drainage member through which the water separated by the separation unit is discharged; a supply member which supplies air to the separation unit to vaporize the chlorine containing organic solvent; and an exhaust member through which the air supplied by the supply member and/or vaporized chlorine containing organic solvent is discharged.

The porous material used for the separation member according to an embodiment of the invention may be made of a sintered compact of a water-repellent and/or lipophilic polyolefine type resin or fluororesin. Examples of the polyolefine type resin include polyethylene (hereinafter abbreviated as "PE"), polypropylene (hereinafter abbreviated as "PP"), and ultrahigh molecular weight polyethylene (hereinafter abbreviated as "UHPE"). Also, examples of the fluororesin include polytetrafluoroethylene (hereinafter abbreviated as "PTFE"). It is preferable to use UHPE having an average molecular weight between about 100,000 and 5,000,000 as the resin forming the porous material according to the present invention.

Moreover, the porous material used in the present invention has continuous pores, and the pore size thereof is preferably between about 10 and 300 μm, and more preferably between about 20 and 100 μm. The ratio of vacancy of the porous material is preferably about 5–50%, and more preferably about 10–30%.

As shown in FIGS. **1**A through **1**D, the separation member used in the present invention may be in the shape of a film, plate, tube, container, or granule.

The size of the separation member of the film or plate shape shown in FIG. **1**A, of the tubular shape shown in FIG. **1**B, and of the container shape shown in FIG. **1**C may be suitably determined in accordance with the size of the solvent separator used. It is preferable that the thickness of the separation member be about 2–10 mm, more preferably be about 5–10 mm.

The separation members shown in FIG. **1**D have a cylindrical shape having an outer diameter of about 1–10 mm, and a length of about 3–10 mm.

When a mixture of water and a chlorine containing organic solvent makes contact with the surface of the separation member, the chlorine containing organic solvent is adsorbed on the surface of the separation member and diffused into the separation member due to its surface tension. Also, since the separation member is made of a water-repellent and/or a lipophilic resin, water cannot permeate the inside thereof, and therefore, it becomes possible to separate the chlorine containing organic solvent from the water.

The separation member of the invention is capable of adsorbing chlorine containing organic solvents, the amount of which corresponds to the weight of the separation member. Accordingly, the amount of the separation member used may be suitably determined in accordance with the expected amount of the chlorine containing organic solvents to be treated in one process.

Next, the solvent separator according to an embodiment of the present invention will be described in detail with reference to FIGS. **2** through **5**.

FIG. **2** is a diagram showing a cross-sectional view of a solvent separator according to an embodiment of the present invention.

The solvent separator **10** in FIG. **2** includes a vessel **1**, an introduction member **2**, a separation unit **3**, a water drainage member **4**, and a solvent drainage member **5**. The introduction member **2** introduces waste liquid discharged from a cleaning device, such as a dry cleaning device, into the vessel **1**. The introduction member **2** may be disposed at the upper portion of the vessel **1**. The separation unit **3** includes a separation member which may be made of a porous material, and separates waste liquid into water and chlorine containing organic solvents. The separation unit **3** is placed in the vessel **1**. The water drainage member **4** discharges water, which has been separated by the separation unit **3**, from the vessel **1**. The water drainage member **4** may be disposed at a side portion of the vessel **1** at a position higher than the position of the separation unit **3**. The solvent drainage member **5** discharges the solvent, which has been separated by the separation unit **3**, from the vessel **1**. The solvent drainage member **5** may be disposed at a side or bottom portion of the vessel **1** at a position lower than the position of the separation unit **3**.

The vessel **1** may be a container in the shape of cylinder, square pole, etc. and may be made of, as a raw material, a polyethylene type resin, a fluororesin, or a stainless steel having excellent corrosion resistance properties, chemical resistance properties and so forth. Also, it is possible to use a container having an inner surface covered by such a resin or a stainless steel, as the vessel **1**. The size of the vessel **1** may be suitably determined based on the amount of solvents treated.

For the introduction member **2**, the water drainage member **4**, and the solvent drainage member **5**, a tube made of a polymeric material, such as a fluororesin, a polyester type resin, or a nylon type resin, or a metal, such as a stainless steel, having an excellent corrosion resistance properties and chemical resistance properties may be utilized. Also, it is possible to use a tube having an inner surface covered by such a resin or a metal, for the introduction member **2**, the water drainage member **4**, and the solvent drainage member **5**.

The separation unit **3** includes a separation member which is formed by a porous material of a film or plate shape having the thickness of about 2–10 mm. The size of the separation member may be suitably determined in accordance with such factors as the amount of solvents treated or the size of the solvent separator **10**.

When waste liquid is introduced into the vessel **1** via the introduction member **2** and makes contact with the separation member of the separation unit **3**, only chlorine containing organic solvents contained in the waste liquid are adsorbed by and permeate through the separation member of the separation unit **3**. The chlorine containing organic solvent is then discharged from the vessel **1** through the solvent drainage member **5** which is disposed at the lower portion of the solvent separator **10**. On the other hand, water and/or a chlorine containing organic solvent dissolved in water, which does not permeate through the separation member of the separation unit **3**, is discharged from the vessel **1** via the water drainage member **4**.

The solvent separator **10** may be suitably used for cases where a chlorine containing organic solvent is separated by utilizing a difference in specific gravity.

FIG. **3** is a diagram showing a cross-sectional view of a solvent separator according to another embodiment of the invention.

In FIG. **3**, a solvent separator **20** includes a vessel **11**, an introduction member **12**, a separation unit **13**, and a drainage member **14**. The introduction member **12** is used to supply air for vaporizing a chlorine containing organic solvent which is discharged from a cleaning device, such as a dry cleaning device. The introduction member **12** may be disposed at the upper portion of the vessel **11**. The separation unit **13** includes a separation member which may be made of a porous material, and separates the waste liquid into water and a chlorine containing organic solvent. The separation unit **13** is disposed in the vessel **11**. The drainage member **14** is to discharge water or chlorine containing organic solvent, which is separated by the separation unit **13**, from the vessel **11**. The drainage member **14** may be disposed so as to start at a location near the bottom of the vessel and pass through the top thereof.

The vessel **11** may be a container in the shape of cylinder, square pole, etc. and may be made of, as a raw material, a polyethylene type resin, a fluororesin, or a stainless steel having excellent corrosion resistance properties, chemical resistance properties, etc. Also, it is possible to use a container having an inner surface covered by such a resin or a stainless steel, as the vessel **11**. The size of the vessel **11** may be suitably determined based on the amount of solvent treated.

For the introduction member **12**, and the drainage member **14**, a tube made of a polymeric material, such as a fluororesin, a polyester type resin, or a nylon type resin, or a metal, such as a stainless steel, having excellent corrosion resistance properties and chemical resistance properties may be utilized. Also, it is possible to use a tube having an inner surface covered by such a resin or a metal, for the introduction member **12**, and the drainage member **14**.

The separation unit **13** includes a separation member which is formed by a porous material of a cylindrical granular shape having a diameter of about 1–10 mm and a length of about 3–10 mm. The separation member may be added to the vessel **11** and the amount thereof may be suitably determined in accordance with such factors as the amount of solvent treated or the size of the vessel **11**.

When waste liquid is introduced into the vessel **11** via the introduction member **12** and makes contact with the separation member of the separation unit **13**, only the chlorine containing organic solvent contained in the waste liquid is adsorbed by the separation member of the separation unit **13**. Water and/or a chlorine containing organic solvent still dissolved in the water are discharged from the vessel **11** via the drainage member **14**.

After discharging the water and/or chlorine containing organic solvent dissolved in the water, air is supplied to the separation member via the introduction member **12** in order to vaporize the chlorine containing organic solvent adsorbed by the separation member and to discharge it through the drainage member **14**. In this manner, the discharge of the gasified chlorine containing organic solvent is completed, and the separation member of the separation unit **13** is regenerated. After this, it becomes possible to reuse the separation member and adsorb chlorine containing organic solvent, the amount of which corresponds to the weight of the separation member, when waste liquid is introduced into the vessel **11** via the introduction member **12**.

Although it is possible to use untreated atmospheric air and supply it through the introduction member **12** in order to vaporize and discharge chlorine containing organic solvent, it is preferable to dry or heat the air prior to supplying it to the vessel **11** in order to enhance the vaporization efficiency. When applying heat to the air, it is preferable to heat the air to a temperature equal to or higher than the boiling temperature of the chlorine containing organic solvent to be collected.

Since the solvent separator **20** according to this embodiment of the invention collects the chlorine containing organic solvent by adsorbing it onto the separation member and then vaporizing it, it becomes possible to collect the chlorine containing organic solvent efficiently. Also, the separation member may be easily regenerated for its next use.

FIG. **4**A is a diagram showing a cross-sectional view of a solvent separator according to another embodiment of the present invention. FIG. **4**B is a diagram showing a side view of the solvent separator shown in FIG. **4**A.

In FIGS. **4**A and **4**B, a solvent separator **30** includes a vessel **21**, an introduction member **22**, a supply member **23**, a separation unit **24**, a water drainage member **25**, and a solvent exhaust member **26**. The introduction member **22** is to introduce waste liquid discharged from a cleaning device, such as a dry cleaning device, into the vessel **21**. The supply member **23** supplies air to the separation unit **24** in order to vaporize chlorine containing organic solvent. The separation unit **24** includes a separation member which may be made of a porous material, and separates the waste liquid into water and a chlorine containing organic solvent. The water drainage member **25** discharges water which is separated from the waste liquid. The solvent exhaust member **26** discharges chlorine containing organic solvent which has been vaporized. Also, the vessel **21** has a structure in which it is divided into an inner vessel **27** and an outer vessel **28** by the separation unit **24**.

The vessel **21** may be a container of cylindrical shape and made of, as a raw material, a polyethylene type resin, a fluororesin, or a stainless steel having excellent corrosion resistance properties, chemical resistance properties etc. Also, it is possible to use a container having its inner surfaces covered by such a resin or a stainless steel, as the vessel **21**. The size of the vessel **21** may be suitably determined based on the amount of solvent treated.

For the introduction member **22**, the supply member **23**, the water drainage member **25**, and the solvent exhaust member **26**, a tube made of a polymeric material, such as a fluororesin, a polyethylene type resin, or a nylon type resin, or a metal, such as a stainless steel, having excellent corrosion resistance properties and chemical resistance properties may be utilized. Also, it is possible to use a tube with an inner surface covered by such a resin or a metal, for the introduction member **22**, the supply member **23**, the water drainage member **25**, and the solvent exhaust member **26**.

The separation unit **24** includes a separation member which is made of a porous material of cylindrical shape having a thickness of about 2–10 mm. The size of the separation member may be suitably determined in accordance with such factors as the size of the vessel **21**, however, it is preferable to use one having a longer length in order to increase the contact area with the solvent.

When waste liquid is introduced into the inner vessel **27** of the vessel **21** via the introduction member **22** and makes contact with the separation member of the separation unit **24**, only the chlorine containing organic solvent contained in the waste liquid is diffused into and permeates through the separation member of the separation unit **24** to reach the outer vessel **28**. When the chlorine containing organic solvent makes contact with air which is supplied to the outer vessel **28** via the supply unit **23**, the chlorine containing organic solvent is vaporized and discharged via the solvent exhaust member **26**.

Although it is possible to use untreated atmospheric air and supply it through the supply member **23** in order to vaporize the chlorine containing organic solvent and discharge it outside the vessel **21**, it is preferable to dry or heat the air prior to supplying it to the vessel **21** in order to enhance the vaporization efficiency. When applying heat to the air, it is preferable to heat the air to a temperature equal to or higher than the boiling temperature of the chlorine containing organic solvent to be collected.

Since the solvent separator **30** according to this embodiment of the invention is capable of continuously carrying out the introduction of waste liquid, the separation, vaporization, and discharge of the chlorine containing organic solvent, the discharge of water and/or chlorine containing organic solvent dissolved in water, and the regeneration of the porous material which constitutes the separation unit **24**, it is possible to efficiently carry out the separation of chlorine containing organic solvent.

FIG. **5** is a diagram showing a cross-sectional view of a solvent separator according to another embodiment of the present invention.

In FIG. **5**, a solvent separator **40** includes a vessel **31**, an introduction member **32**, a separation unit **33**, a solvent exhaust member **34**, a water drainage member **35**, and a supply member **36**. The introduction member **32** introduces waste liquid discharged from a cleaning device, such as a dry cleaning device, into the vessel **31**. The introduction member **32** may be disposed at the upper portion of the vessel **31**. The separation unit **33** includes a separation member which may be made of a porous material, and separates the waste liquid into water and a chlorine containing organic solvent. The separation unit **33** is placed in the vessel **31**. The solvent exhaust member **34** discharges a chlorine containing organic solvent, which is separated by the separation unit **33**, from the vessel **31**. The solvent exhaust member **34** may be disposed at a side portion of the vessel **31** at a position higher than the position of the separation unit **33**. The water drainage member **35** discharges water and/or a chlorine containing organic solvent dissolved in water, which are separated by the separation unit **33**, from the vessel **31**. The water drainage member **35** may be disposed at a side or bottom portion of the vessel **31** at a position lower than the position of the separation unit **33**. The supply member **36** supplies air to the separation unit **33** in order to vaporize the chlorine containing organic solvent. The supply member **36** may be disposed at a side portion of the vessel **31** at a position lower than the position of the separation unit **33**.

The vessel **31** may be a container in the shape of a cylinder, square pole, etc. and may be made of, as a raw material, a polyethylene type resin, a fluororesin, or a stainless steel, which has excellent corrosion resistance properties, chemical resistance properties and so forth. Also, it is possible to use a container having an inner surface coated by such a resin or a stainless steel, as the vessel **31**. The size of the vessel **31** may be suitably determined based on the amount of solvent treated.

For the introduction member **32**, the solvent exhaust member **34**, the water drainage member **35**, and the supply member **36**, a tube made of a polymeric material, such as a fluororesin, a polyethylene type resin, or a nylon type resin, or a metal, such as a stainless steel having excellent corrosion resistance properties and chemical resistance properties may be utilized. Also, it is possible to use a tube having its surface covered by such a resin or a metal, for the introduction member **32**, the solvent exhaust member **34**, the water drainage member **35**, and the supply member **36**.

The separation unit **33** includes a separation member which is formed by a porous material in the shape of cylindrical granules having a diameter of about 1–10 mm and a length of about 3–10 mm. The separation member may be filled in the vessel **31** and the amount thereof may be suitably determined in accordance with such factors as the amount of solvent treated or the size of the vessel **31**.

When waste liquid is introduced into the vessel **31** via the introduction member **32**, it may be dispersed onto the granular separation member from the top of the vessel **31** so that the chlorine containing organic solvent in the waste liquid may be easily diffused into the separation member, which constitutes the separation unit **33**, from the surface thereof. When the waste liquid makes contacts the separation member, only the chlorine containing organic solvent contained in the waste liquid is adsorbed by the separation member of the separation unit **33**. Water, which is not adsorbed by the separation member, and/or chlorine containing organic solvent still dissolved in water are discharged via the water drainage member **35**. Also, when air is supplied to the separation unit **33** via the supply member **36** which is disposed at the lower portion of the vessel **31**, the chlorine containing organic solvent adsorbed by the porous materials which forms the separation unit **33** is vaporized and discharged via the solvent exhaust member **34**.

Although it is possible to use untreated atmospheric air and supply it to the separation member **33** via the supply member **36** in order to vaporize the chlorine containing organic solvent and discharge it outside the vessel **31** it is preferable to dry or heat the air prior to supplying it into the vessel **31** in order to enhance the vaporization efficiency. When applying heat to the air, it is preferable to heat the air to a temperature equal to or higher than the boiling temperature of the chlorine containing organic solvent to be collected.

Since the solvent separator **40** according to the embodiment of the invention is capable of continuously carrying out the introduction of waste liquid, the separation, vaporization, and discharge of the chlorine containing organic solvent, the discharge of water and/or chlorine containing organic solvent dissolved in water, and the regeneration of the porous material which constitutes the separation unit **33**, it is possible to efficiently carry out the separation of chlorine containing organic solvent.

FIG. **6** is a diagram showing a waste liquid processing device of a dry cleaning device in which the solvent separator according to an embodiment of the present invention is employed. In FIG. **6**, the solvent separator **20** shown in FIG. **3** is used in the waste liquid processing device of a dry cleaning device.

The waste liquid processing device of the dry cleaning device in this embodiment includes the solvent separator **20** of the present invention, a waste liquid tank **41**, a photo-oxidation decomposition processing unit **42**, an after-treatment unit **43**, and a vaporization treatment unit **60**. The waste liquid tank **41** is used to temporarily store waste liquid discharged from the dry cleaning device. The photooxidation decomposition processing unit **42** photooxidizes and decomposes the chlorine containing organic solvent which has been separated and vaporized by the solvent separator **20**.

Next, a process for treating a waste liquid using the above-mentioned waste liquid processing device will be described as follows.

First, waste liquid discharged from the dry cleaning device is collected and stored in the waste liquid tank **41**. Then, the waste liquid is introduced into the solvent separator **20** via a waste liquid supply member **44** and the introduction member **12**. The chlorine containing organic solvent which is dispersed in the waste liquid is adsorbed by the separation member of the separation unit **13**, which is made of a porous material, and water and/or chlorine containing organic solvent still dissolved in the water are discharged to the vaporization treatment unit **60** via the drainage member **14**. Compressed air is supplied into an aeration vessel **51** through a compressed air supply member **52** of the vaporization treatment unit **60** in order to vaporize the chlorine containing organic solvent contained in the waste liquid. The vaporized solvent is then introduced into the photooxidation decomposition processing unit **42** via the drainage member **14**, the solvent separator **20**, the introduction member **12**, and the vaporized gas supply member **45**. Also, the chlorine containing organic solvent, which has been adsorbed by the separation member, is vaporized by the compressed air supplied from the compressed air supply member **52**, and is introduced into the photooxidation decomposition processing unit **42** via the introduction member **12** and the vaporized gas supply member **45**. The vaporized chlorine containing organic solvent is photooxidized in the photooxidation decomposition processing unit **42**, and decomposition product gases containing chlorine gas generated by a photooxidation decomposition reaction are introduced into the after-treatment unit **43** via a decomposition product gas supply member **46** so that the gases are absorbed, adsorbed, neutralized, and converted into nontoxic salts in the after-treatment unit **43**.

An aeration method is used in the above-mentioned vaporization treatment unit **60**. As shown in FIG. **6**, the vaporization treatment unit **60** includes the drainage member **14**, the compressed air supply member **52**, an air diffuser member **53**, and a drainage outlet **54**. The drainage member **14** introduces waste liquid discharged from the solvent separator **20** into the aeration vessel **51** and discharges solvent gases which have been subjected to an aeration process. The compressed air supply member **52** is used to supply compressed air. The air diffuser member **53** is used to disperse the compressed air in the waste liquid. The drainage outlet **54** discharges drainage which has been subjected to the aeration process.

In this specification, the term "waste liquid" may mean a fluid to be treated, which is introduced into the waste liquid processing device of the present invention to be rendered nontoxic. On the other hand, the term "drainage" may mean a treated fluid, which has been subjected to a process of the waste liquid processing device to be rendered nontoxic.

The size of the aeration vessel **51** may be suitably determined in accordance with the amount of a fluid to be treated, and the aeration vessel **51** may be made of, as a raw material, a polymeric material, such as a fluororesin or a polyethylene type resin, or a metal, such as a stainless steel, having excellent corrosion resistance properties, chemical resistance properties, and water-repellent properties. Also, it is possible to use a container having inner surfaces coated by such a resin or a metal, for the aeration vessel **51**.

Moreover, an agitation device of jet type, propeller type, etc. may be disposed in the aeration vessel **51** in order to increase the aeration efficiency.

Further, as a source for compressed air which is supplied from the compressed air supply member **52** and is used for the aeration process, one which is generally employed in the cleaning industry or washing industry may be utilized.

In addition, the vaporized gas supply member **45** may be made of a polymeric material, such as a fluororesin, a polyethylene type resin, or a nylon type resin, having an excellent corrosion resistance properties, and which is connected to the photooxidation decomposition processing unit **42**.

The photooxidation decomposition processing unit **42** includes a photocatalyst reaction unit and an artificial light irradiation unit, which are disposed in a gas passage duct through which the vaporized gas supplied from the vaporized gas supply member **45** passes. Photocatalyst granules, which carry out the photooxidization and decomposition of organic materials in a gas, are contained in the photocatalyst reaction unit. The artificial light irradiation unit includes an ultraviolet light source which irradiates ultraviolet rays onto the photocatalyst granules.

An example of the above-mentioned photocatalyst granules is a mixture of an inorganic powder, which adsorbs chlorine containing organic gases or chlorine gases, and photocatalyst particles.

Examples of the above-mentioned inorganic powder include, for instance, powders of calcium silicate, calcium carbonate, sodium carbonate, lime, kaolin clay, wallastnite, talc, nepheline-sinite, zeolite, and activated carbon. These may be used singularly or in mixtures of two or more.

Examples of the above-mentioned photocatalyst particles include these which may be activated by the irradiation of light, for example, intravital ultraviolet, and enhance the photooxidation decomposition reaction of organic compounds which make contact with the photocatalyst particles. More concrete examples of such photocatalyst include TiO_2, CdS, $SrTiO_3$, and Fe_2O_3. In particular, use of TiO_2, which has an excellent performance and is obtainable at a low cost, is most preferable.

The content of the photocatalyst particles with respect to the above-mentioned photocatalyst granules is about 10–95 wt. %, preferably about 30–70 wt. %, and more preferably about 40–60 wt. %. If the content of the photocatalyst particles is less than 10 wt. %, the photooxidation decomposition capacity is decreased and there is a danger that chlorine containing organic gases may be discharged without being decomposed. If the content of the photocatalyst particles is greater than 95 wt. %, the ability of the photocatalyst granules to adsorb and retain chlorine containing organic gases is decreased and, when chlorine containing organic gases are rapidly introduced at high concentrations, there is the danger that the chlorine containing organic gases will not be captured and will be discharged without being decomposed.

Also, among the above-mentioned photocatalyst granules, those subjected to a compression molding process to be granular shape are suitably used. Examples of the shapes of the photocatalyst granules include spheres, barrels, short rods, ovoid, and tablets (i.e., a cylinder-like shape). Moreover, it is possible to form holes in the photocatalyst granules or projection on the surfaces thereof.

The particle size of the above-mentioned photocatalyst granules is about 1–20 mm, and preferably about 2–10 mm. Also, the average particle size of the above-mentioned photocatalyst granules is about 4–8 mm, and preferably about 5–7 mm. If the particle size is less than 1 mm, the photocatalyst granules may be clogged and the amount of gas passing through the photocatalyst reaction portion decreases. Accordingly, the photooxidation decomposition efficiency tends to decrease. If the particle size of the photocatalyst granules exceeds 20 mm, the specific surface area (i.e., the surface area per unit weight) of the photocatalyst granules decreases, and the light irradiated from an ultraviolet light source may not reach the center of the gas passage tube. Accordingly, the light receiving efficiency of the photocatalyst granules decreases, and hence, the photooxidation decomposition efficiency also tends to decrease.

The after-treatment unit **43** may be made of, as a raw material, a polyethylene type resin, a fluororesin, or a stainless steel having excellent corrosion resistance properties. Also, it is possible to use a container having inner surfaces coated by such a resin or a metal, for the after-treatment unit **43**.

Agents for absorbing, and/or adsorbing, and/or neutralizing decomposition product gases, which are supplied by the decomposition product gas supply member **46**, are provided with the after-treatment unit **43**.

Examples of the above-mentioned agents include, for instance, alkali ion containing water which includes at least one selected from the group consisting of calcium sulfite, calcium silicate, sodium carbonate, sodium bicarbonate, sodium thiosulfate, calcium carbonate, lime, ammonia, caustic soda, sodium bicarbonate; alkali ion water, and water.

The state of the above-mentioned agents is not limited to the liquid phase, and may be a powdery fluidized bed or a mixture of the two.

In the waste liquid processing device having the above-mentioned structure, gases including chlorine containing organic gas, which are vaporized from waste liquid by the vaporization treatment unit **60**, are photooxidized and decomposed by the photooxidation decomposition processing unit **42**, and the decomposition product gas including chlorine gas thus produced is converted into nontoxic salts by the after-treatment unit **43**. Accordingly, it becomes possible to decrease the amounts of drainage discharged after treatment, chlorine containing organic materials contained in the exhaust gas, and chlorine containing gases which are secondary by-products, to be within the emission standard values, and hence, the present invention may contribute to the prevention of environmental pollution.

Also, since the chlorine containing organic materials contained in the waste liquid discharged from such devices as a dry cleaning device are first vaporized in the vaporization treatment unit **60** and then subjected to a photooxidizing decomposition process in the photooxidation decomposition processing unit **42**, it becomes possible to increase the photooxidation decomposition efficiency and to decrease the time or expenses required by the process, as compared with a case where waste liquid is directly subjected to a photooxidation decomposition process.

Moreover, since a mixture of an inorganic powder, which adsorbs chlorine containing organic gases or chlorine gases, and photocatalyst particles is used as the photocatalyst granules, and chlorine containing organic gases are subjected to the photooxidation decomposition process in the state of being adsorbed and retained by the photocatalyst granules, the photooxidation decomposition efficiency is enhanced and undecomposed chlorine containing organic materials are not discharged outside the photooxidation decomposition processing unit **42**.

Next, a concrete embodiment of the present invention will be described. However, it is to be understood that this is for the purpose of illustration only and that various changes and modifications may be made without departing from the scope of the invention.

In this embodiment, the solvent separator **20** shown in FIG. **3** was employed. Also, in the solvent separator **20**, a container having an outer diameter at its bottom surface of 80 mm and a height of 140 mm and having the shape of cylinder was used as the vessel **11**. Moreover, a separation unit made of a porous material comprising a sintered compact of UHPE having an average molecular weight of between 100,000 and 5,000,000 was put into the vessel **11**. The porous material had a pore size of 10–300 μm, and a vacancy ratio of 10–50%. As the introduction member **12** used to introduce air for vaporizing the chlorine containing organic solvent isolated from waste liquid or drainage, a nylon tube having an inner diameter of 4 mm and an outer diameter of 6 mm was employed. Also, as the drainage member **14** for discharging drainage from which the chlorine containing organic solvent has been isolated, or vaporized chlorine containing organic solvent, a tube made of polytetrafluoroethylene having an inner diameter of 4 mm and an outer diameter of 6 mm was utilized.

In addition, a vaporization treatment device (not shown in the figures) having an aeration vessel was used in order to carry out an aeration process for waste liquid from which the chlorine containing organic solvent had been isolated in the solvent separator **20**.

Waste liquid (10 L) having a perchloroethylene (a chlorine containing organic solvent, hereinafter abbreviated as PCE) concentration of 200 mg/l was introduced into the solvent separator **20** and contacted the porous material. After that the PCE concentration of the waste liquid was measured. The results are shown in the row denoted "after solvent separation process" in Table 1.

Then, the aeration process was carried out for 60 minutes, during which the aeration amount and the internal pressure of the aeration vessel were maintained at 20 L/min and 2 kg/cm^2, respectively. The PCE concentration of the waste liquid was measured every 15 minutes.

On the other hand, the PCE concentration of the waste liquid was also measured, for comparison, for the case where only the aeration process was carried out, and the solvent separator **20** was not used.

Results are shown in Table 1 below.

TABLE 1

	PCE conc. (mg/l) with the solvent separator	PCE conc. (mg/l) w/o the solvent separator
Stock solution	200.00	200.00
After solvent separation process	87.50	—
Aeration time (min.)		
0	87.50	200.00
15	0.50	5.00
30	0.10	7.00
45	0.04	1.75
60	0.02	0.43

It can be seen from the results shown in Table 1 that the PCE concentration was significantly decreased when the waste liquid, which had been treated in the solvent separator **20**, was subjected to the aeration process as compared to the case where the waste liquid was subjected to the aeration process only and untreated in the solvent separator **20**. Therefore, the results indicate that almost all the PCE which was dispersed in the waste liquid in an undissolved fine particle state, was adsorbed by the separation unit made of a porous material in the solvent separator **20** of the present invention.

FIG. **7** is a schematic diagram for explaining a waste liquid treatment device according to an embodiment of the present invention.

In FIG. **7**, the waste liquid treatment device includes a solvent separation unit **61**, a waste liquid supply line **62**, a vaporization treatment unit **63**, a vaporized gas supply line **64**, a photooxidation decomposition processing unit **65**, a decomposition product gas supply line **66**, an after-treatment unit **67**, and a control unit **68**. In FIG. **7**, the direction of the flow of chlorine containing organic solvent is indicated by arrows. The solvent separation unit **61** may be connected to the vaporization treatment unit **63** either directly or via the waste liquid supply line **62**. Also, a drainage line for discharging drainage which has been subjected to an aeration process is connected to the vaporization treatment unit **63**.

Moreover, the solvent separation unit **61** is connected to the photooxidation decomposition processing unit **65** via the vaporized gas supply line **64**, and the photooxidation decomposition processing unit **65** is connected to the after-treatment unit **67** via the decomposition product gas supply line **66**. Further, a line for discharging air containing non-harmful water vapor and carbon dioxide emitted from the after-treatment unit **67** is connected to the after-treatment unit **67**. The control unit **68** controls the solvent separation unit **61**, the vaporization treatment unit **63**, the photooxidation decomposition processing unit **65**, and the after-treatment unit **67**.

As mentioned above, the solvent separation unit **61** may be disposed apart from the vaporization treatment unit **63**. In this embodiment, however, the solvent separation unit **61** is disposed in the pathway before the front portion of the vaporization treatment unit **63**, and selectively adsorbs the chlorine containing organic solvent which is dispersed in a fine particle state in waste liquid. In the next step, waste liquid which contains the chlorine containing organic solvent which has not been adsorbed by the solvent separation unit **61** is subjected to a vaporization treatment during an aeration process in the vaporization treatment unit **63**. The vaporized gas containing vaporized chlorine containing organic gas which is generated in this process passes through the solvent separation unit **61** again. The vaporized gas vaporizes the chlorine containing organic solvent which has been adsorbed by the solvent separation unit **61** as it passes through the solvent separation unit **61**, and all of these vaporized gases are introduced into the photooxidation decomposition processing unit **65** via the vaporized gas supply line **64**. Then, the vaporized gases are photooxidized and decomposed by the photooxidation decomposition processing unit **65**, and decomposition product gases containing chlorine gas generated by the photooxidation-decomposition reaction are introduced into the after-treatment unit **67** via the decomposition product gas supply line **66** so that the decomposition product gases are adsorbed, absorbed, and neutralized in the after-treatment unit **67** and converted into harmless salts. As a final step, a drainage treatment or exhaust treatment is carried out.

Next, a waste liquid treatment device according to another embodiment of the present invention will be described with reference to FIGS. **8** through **11**.

FIG. **8** is a diagram showing a schematic perspective view of a waste liquid treatment device according to an embodiment of the present invention. FIG. **9** is a diagram showing a schematic elevational view of the waste liquid treatment device shown in FIG. **8**, some parts of which are shown in perspective. FIG. **10** is a diagram showing the side view of the waste liquid treatment device shown in FIG. **8**, some parts of which are shown in perspective (and may be in cross-sectional). FIG. **11** is a diagram showing a schematic plan view of the waste liquid treatment device shown in FIG. **8**, some parts of which are shown in perspective. In FIGS. **8** through **11**, a separation member **72**, which is formed by a porous material, is contained in the solvent separation unit **61**.

As shown in FIG. **8**, the solvent separation unit **61** has a structure in which the separation member **72** including granular porous materials is contained in a separation vessel **71** which is disposed at the upper portion of an aeration vessel **70**.

The separation vessel **71** has a diameter of about 3–15 cm and a height of about 3–10 cm. The separation vessel **71** may be a container of cylindrical shape whose outer diameter is almost equal to the inner diameter of the upper portion of the aeration vessel **70**, and whose upper and the lower surfaces may be in a mesh form. The separation vessel **71** may be made of, as a raw material, a polymeric material, such as a fluororesin or a polyethylene type resin, or a metal such as stainless steel, having excellent corrosion resistance properties, chemical resistance properties, and water-repellence properties. Also, it is possible to use a container made of a stainless steel having inner surfaces coated by such a resin, for the separation vessel **71**.

Examples of the material which forms the separation member **72** contained in the separation vessel **71** include activated carbon, zeolite, and porous materials, such as a sintered compact of a water-repellent and/or lipophilic resin, which are capable of selectively adsorbing chlorine containing organic solvents in a waste liquid. Among them, it is preferable to use a porous material formed by a sintered compact of a water-repellent and/or lipophilic resin.

The separation member **72** has continuous pores and the pore size thereof is about 10–300 μm, preferably about 20–100 μm, and the vacancy ratio thereof is 5–50%, preferably about 10–30%.

Also, the shape of the separation member **72** may be spheres, cylinders, barrels, or rods having a volume of about 1–1,000 mm^3.

Moreover, the separation member **72** used in the present invention is capable of adsorbing a chlorine containing organic solvent in an amount corresponds to the weight thereof. Accordingly, the amount of the porous material may be suitably determined based on the amount of chlorine containing organic solvent expected to be treated in one process.

According to this embodiment of the present invention, waste liquid is supplied to the solvent separation unit **61** from the upper central portion of the aeration vessel **70**. When the waste liquid passes through the separation member **72**, chlorine containing organic solvent in a fine particle state present in the waste liquid is selectively adsorbed by the separation member **72**.

Note that the solvent separation member **61** is not limited to the one mentioned above in which the separation member **72** in a granular state is contained in the separation vessel **71**, and may be formed by a separation member **72** in the shape of a film, plate, or a grid.

The size of the separation member **72** in the shape of a film, plate, or grid may be suitably determined in accordance with the size of the aeration vessel **70**, and the thickness thereof may be in the range between about 0.5 and 10 mm, preferably in a range between about 1 and 3 mm.

Examples of the water-repellent and/or lipophilic resin which may be used for the separation member **72** include polyolefin resins, fluororesins, and silicone resins. Examples of the polyolefin resin include PE, PP, and UHPE, and an example of the fluororesin is PTFE. It is preferable to use a UHPE having an average molecular weight of between about 100,000 and 5 million as the water-repellent and/or lipophilic resin used in the present invention.

In this embodiment, an aeration treatment unit is used as the vaporization treatment unit **63**. As shown in FIGS. **8** through **10**, the aeration treatment unit includes a waste liquid inlet portion **73**, a vaporized gas outlet portion **75**, a drainage outlet portion **77**, and a compressed air inlet portion **78**. The waste liquid inlet portion **73** which is used for introducing waste liquid, the vaporized gas outlet portion **75** which is used for discharging gases after the aeration process, and a gas intake portion (not shown in the figures) having a check valve may be disposed above the aeration vessel **70**. On the other hand, the drainage outlet portion **77** which is used for discharging drainage after the aeration process, and the compressed air inlet portion **78** which is used for supplying a compressed air may be disposed below the aeration vessel **70**.

The aeration vessel **70** has a diameter of about 3–15 cm and a height of about 10–30 cm. The aeration vessel **70** may be a pressure vessel of cylindrical shape, which is made of, as a raw material, a polymeric material such as a fluororesin or a polyethylene type resin having excellent corrosion resistance properties, chemical resistance properties, and water-repellence properties. Also, it is possible to use a container having inner surfaces coated by such a resin, for the aeration vessel **70**.

Moreover, an agitation device of jet type, propeller type, etc. may be disposed in the aeration vessel **70** in order to increase the aeration efficiency.

The waste liquid inlet portion **73** is connected to a waste liquid supply unit (not shown in the figures) via a waste liquid supply line **74**.

A waste liquid vessel of the waste liquid supply unit may be a container having the volume of 20 L or less, which is made of, as a raw material, a polymeric material such as a fluororesin or a polyethylene type resin, or a metal such as a stainless steel, having excellent corrosion resistance properties, chemical resistance properties, and water-repellence properties. Also, it is possible to use a container made of stainless steel having inner surfaces coated by such a resin, for the waste liquid vessel. Moreover, the drainage line from the water separator of the cleaning device, such as a dry cleaning device, is connected to the waste liquid vessel either directly or via a filter for removing dust. Further, a liquid level sensor for detecting the upper and the lower limits of the waste liquid may be provided with the waste liquid vessel.

In addition, a waste liquid supply pump is disposed in the above-mentioned waste liquid vessel and supplies waste liquid to the solvent separation unit **61** from the waste liquid vessel via the waste liquid supply line **74** and the waste liquid inlet portion **73** when a signal from the control unit (to be described below) is received. Also, a check valve is disposed at the outlet of the waste liquid supply pump so that the aeration gas does not flowup into the waste liquid vessel due to the air pressure in the aeration process. Note that an electromagnetic valve may be used instead of the check valve. Also, a pump for domestic use, such as one for drawing water in a bath, may be used as the waste liquid supply pump.

The drainage outlet portion **77** may also function as the compressed air inlet portion **78**, and is connected to an intermediate tube **79** which may function as a drainage tube as well as a compressed air introduction tube.

Also, as a source for supplying the compressed air which may be used in the aeration process, an air diffusing pump which may be used for a domestic water tank may be utilized.

Moreover, in order to increase the aeration efficiency, an air diffusing member **80** comprising an air diffusing tube or an air diffusing plate may provided with the compressed air inlet portion **78** at the bottom portion of the aeration vessel **70**.

An air pump **81** may be disposed on the aeration vessel **70** as a source for supplying air which is used for the aeration process. The air pump **81** is connected to the compressed air inlet portion **78** which may be located below the aeration vessel **70** via a compressed air supply tube **82**, a branched joint **79*a*** connected to the IN side of an electromagnetic valve **83**, and the intermediate tube **79**.

As the air pump **81**, an air diffusing pump which may be used for a domestic water tank may be utilized.

A gas intake portion **76** having a check valve may be disposed at the upper portion of the aeration vessel **70** in order to prevent the generation of negative pressure in the aeration vessel **70** during the discharge of the treated drainage, which may stop the discharge of the drainage.

The vaporized gas outlet portion **75** is connected to the photooxidation decomposition processing unit **65** via the vaporized gas supply line **64** so that the vaporized gas after the aeration process may be emitted to the photooxidation decomposition processing unit **65**. Also, the vaporized gas supply line **64** may be made of a polymeric material such as a fluororesin, a polyethylene type resin, or a nylon type resin, having excellent corrosion resistance properties.

The vaporization treatment unit **63** vaporizes the chlorine containing organic solvent adsorbed by the separation member **72** when the vaporized gas which has been subjected to the aeration process passes through the separation member **72**, and supplies air including the chlorine containing organic gas to the photooxidation decomposition processing unit **65**.

Also, the vaporization treatment unit **63**, after discharging the treated drainage from the aeration vessel **70**, supplies air by means of the air pump **81** so that the chlorine containing organic solvent, which was adsorbed by the separation member **72** but was not completely vaporized in the aeration air, can be vaporized in an efficient manner.

As shown in FIG. **10**, the photooxidation decomposition processing unit **65** includes a photocatalyst reaction portion **86**, artificial light irradiation members **89**, and a reflection board member **90**, all of which are disposed in a gas flow line **84** through which a vaporized gas supplied from the vaporized gas supply line **64** passes. As shown in the figure, photocatalyst granules **85**, which photooxidize and decompose the chlorine containing organic materials in a gas, are contained in the photocatalyst reaction portion **86**. The artificial light irradiation member **89** includes an ultraviolet light source **88** for irradiating ultraviolet rays onto the photocatalyst granules **85**. As shown in FIG. **11**, the artificial light irradiation members **89** are disposed so as to oppose the photocatalyst reaction portion **86**.

The gas flow line **84** includes an inlet portion (not shown in the figures) located at an upper portion of a gas flow line connection fixing portion **91** and an outlet portion **84***c* located at the lower portion thereof. In the gas flow line **84**, three straight tube members **84***a* are arranged in the same vertical face with a pitch interval of about 8–35 mm, and the adjacent straight tube members **84** are connected to each other by connection members **92** so as to form a single long gas passage.

Also, aeration gas supply port **91** a, which is connected to the first straight tube (glass tube) **84***a*, is disposed at the upper portion of the gas flow line connection fixing portion **91**, and a decomposition product gas discharge port **91***b*, which is connected to the third straight tube (glass tube) **84***a*, is disposed at the lower portion of the gas flow line connection fixing portion **91**.

Examples of materials used for making the straight tube members **84***a* include those which transmit artificial light, such as ultraviolet light, or natural light, and transparent materials, such as borosilicate glass or synthetic resins, may be employed.

The inner diameter of the straight tube members **84***a* may be in the range between about 5 and 30 mm, preferably in the range between about 8 and 16 mm. If the inner diameter is smaller than 5 mm, the photooxidation-decomposition treatment efficiency is decreased due to the decrease in the amount of the photocatalyst granules **85** contained in the gas flow line **84**. Also, the system throughput is decreased due to the decrease in the gas flow caused by the small diameter of the straight tube member **84***a*. If the inner diameter of the straight tube members **84***a* exceeds 30 mm, on the other hand, light irradiated from the ultraviolet light source **88** will scarcely reach the center portion of the straight tube member **84***a*, and the photooxidation-decomposition treatment efficiency will decrease due to the decrease in the light receiving efficiency of the photocatalyst granules **85**.

Also, the length of the straight tube members **84***a* is determined to be within the range of about 200–800 mm. It is preferable that the length of the straight tube members **84***a* be substantially equal to the length of the ultraviolet light source **88**.

In this manner, ultraviolet light from the ultraviolet light source **88** may be uniformly irradiated onto the photocatalyst granules **85** over the entire photocatalyst reaction portion **86**.

Also, holding members (not shown in the figures) for holding the photocatalyst granules **85** in the straight tube member **84** are disposed at both ends of the straight tube member **84**. Examples of the materials which can be used for the holding member include a polymeric material such as a fluororesin, a polyethylene type resin, or a nylon type resin having excellent corrosion resistance properties. The materials used for the holding member should have a structure which enables a gas flow therethrough, and it is preferable that the diameter thereof be substantially the same as the inner diameter of the straight line **84***a* with a thickness of about 5–30 mm.

Examples of the photocatalyst granules include a mixture of an inorganic powder, which adsorbs chlorine containing organic gases or chlorine gases, and photocatalyst particles. Concrete examples of the inorganic powder and the photocatalyst particles, the amount of the photocatalyst particles contained in the photocatalyst granules **85**, and the shape and the particle size of the photocatalyst granules are substantially the same as the ones described above and their explanation is omitted.

The connection member **92** includes a body portion (not shown in the figures), which connects the end portions of the straight tube member **84***a*, a cover portion (not shown in the figures), which may be attached to the body portion, and an O-ring (not shown in the figures), which is an annular sealing member.

The body portion may be a rectangular member having an opening part in which an end portion of the straight tube member **84***a* is inserted. Gases or air passes through a passage (not shown in the figures) provided in the body portion from one of the straight tube member **84***a* to the other which is inserted in the opening part of the body portion.

It is preferable that the inner surfaces of the passage be coated by a polymeric material, such as a fluororesin or a polyethylene type resin, having an excellent corrosion resistance properties, chemical resistance properties, etc., or that the body portion itself be formed by a metal, such as hastelloy, or a polymeric material, such as a fluororesin, a polyethylene type resin, or a PPS, having excellent corrosion resistance properties and chemical resistance properties.

A tapered portion for accommodating the O-ring, which gradually increases its diameter towards the end of the opening part, is formed at the periphery of the opening part, and the O-ring is disposed between the tapered portion and the straight tube member **84***a*.

The cover portion includes holes in which the straight tube member **84***a* is inserted, and is attached to the body portion so as to contact the opening end of the body portion.

The O-ring is disposed, as mentioned above, between the tapered portion and the straight tube member **84***a* so as to contact all of the body portion, the cover portion, and the outside surface of the straight tube member **84***a*. The O-ring may be made of an elastic material, such as a rubber, and it is preferable that the O-ring be in an elastically deformed state being compressed by the body portion and the cover portion.

Also, the diameter of the opening part at the upper end side of the main portion and the diameter of the hole of the cover portion are designed to be larger than the outer diameter of the straight tube member **84***a* so that the straight tube member **84***a* may be moved in its lengthwise direction.

Moreover, the straight tube member **84** is designed so that when it is moved upwards, the lower end of the straight tube member **84** detaches from the upper face of the cover member, and the straight tube member **84** may be inclined in order to allow for easy replacement of the straight tube member **84***a* without removing the cover portion. Assuming that the length of the lower end of the straight tube member **84***a* which is inserted into the cover portion and the body portion is "a". and the distance between the upper end of the straight tube member **84***a* and the furthermost part of the passage in the body portion is "b", these are designed so that b>a.

Further, a member which is smaller than the outer diameter of the straight tube member **84***a* is disposed in the opening part at the lower end of the body portion so that the length of the straight tube member **84***a* which is inserted into the opening part does not exceed the length "a" and that the straight tube member **84***a* is equally inserted at the upper and the lower end portions thereof.

As shown in FIGS. **10** and **11**, the artificial light irradiation members **89** are disposed at the front and the back of the photocatalyst reaction portion **86**, and include the two ultraviolet light sources **88** of straight tube shape, which are disposed at opposite sides of the photocatalyst reaction portion **86**, and a holder **88**_a_ of a rectangular plate shape can be used for holding the ultraviolet light sources **88**.

The ultraviolet light sources **88** are disposed vertically so that the ultraviolet light is uniformly irradiated onto the entire photocatalyst reaction portion **86**.

An excimer lamp or a black light commonly used may be employed as the ultraviolet light sources **88**.

The reflection board member **90** is disposed so as to surround the photocatalyst reaction portion **86** and the artificial light irradiation members **89**. The reaction board member **90** is designed to reflect the light irradiated from the ultraviolet light source **88** in a highly efficient manner in order to irradiate the photocatalyst granules **85**. Also, it is structured so that the light does not leak from the inside to the outside. As shown in FIG. **11**, it is preferable that the reflection board member **90** be disposed to have a hexagonal cross section in a horizontal direction.

Examples of materials which may be used for the reflection board member **90** include aluminum, stainless steel, and copper, and the reflection board member **90** should have a smooth surface and an excellent heat radiation properties.

The decomposition product gas, which has been decomposed in the photooxidation decomposition processing unit **65**, passes through the outlet portion **84**_c_, the decomposition product gas discharge port **91**_b_, and the decomposition product gas supply line **66** to reach the after-treatment unit **67**.

Also, a liquid level sensor **97** for detecting the level of liquid in the aeration vessel **70**, which is located at an intermediate portion of the aeration vessel **70**, may be disposed at the outside surface of the photooxidation decomposition processing unit **65**.

Moreover, the control unit **68** is disposed adjacent to the photocatalyst reaction portion **86**, and may be covered by a cover member **99** to prevent it from being affected by the heat generated by the ultraviolet light sources **88**.

The control unit **68** includes an earth leakage breaker **100**, a sequencer **101**, an outlet **102** for a pump, an inverter circuit **103** for an ultraviolet light source, and a cover member **99**. The control unit **68** can control the entire waste liquid treatment device including the solvent separation unit **61**, the vaporization treatment unit **63**, the photooxidation decomposition processing unit **65**, and the after-treatment unit **67**, and the automatic operation of the device may be carried out by the sequencer **101**.

Also, a treated drainage discharge unit, which includes the intermediate tube **79** connected to the lower portion of the aeration vessel **70**, the electromagnetic valve **83**, a waste liquid tube **104**, and a treated drainage storage vessel, is provided so that treated drainage is discharged, due to its weight, to the drainage storage vessel when the electromagnetic valve **83** is opened. The intermediate tube **79** and the branched joint **79**_a_ to which the compressed air supply tube **82** is connected in order to supply air from the air pump **81** for the aeration process, are provided at the IN side of the electromagnetic valve **83**. The intermediate tube **79** may be used for discharging treated drainage as well as for supplying air.

The treated drainage storage vessel always maintains a fill-up state so that waste liquid overflowed from the vessel is naturally discharged. Also, it is designed so that the concentration of the treated drainage may be confirmed at any time.

As shown in FIG. **7**, the decomposition product gas supply line **66** is connected to the after-treatment unit **67**.

The after-treatment unit **67** may be a treatment vessel having a decomposition product gas inlet portion and an exhaust gas outlet portion.

Also, it is preferable that the decomposition product gas supply line **66**, the treatment vessel, and the decomposition product gas inlet portion be formed by a polymeric material such as a fluororesin, a polyethylene type resin, or a nylon type resin, having excellent corrosion resistance properties and chemical resistance properties.

The treatment vessel may be a substantially square pole vessel having a bottom surface area of about 100–300 cm^2, a height of about 100–500 cm, and a volume of about 10–30 L. The treatment vessel may be made of a polyethylene type resin, or a fluororesin, having an excellent corrosion resistance properties. Also, it is possible to use a container having inner surfaces coated by such resins, as the treatment vessel.

As mentioned above, agents for absorbing, adsorbing, and neutralizing decomposition product gases, which are supplied from the decomposition product gas inlet portion, are provided in the treatment vessel.

Also, it is preferable that an air diffusing member comprising an air diffusing tube or an air diffusing plate be provided inside of the treatment vessel at the decomposition product gas inlet portion in order to increase the after-treatment efficiency.

The solvent separation unit **61**, the vaporization treatment unit **63**, the photooxidation decomposition processing unit **65**, and the after-treatment unit **67**, which are structural components of the waste liquid treatment device, are removable, that whenever a problem occurs, only the component experiencing the problem may be exchanged. The waste liquid treatment device according to an embodiment of the invention has a width of about 5–15 cm, a depth of about 12–25 cm, and a height of about 40–90 cm. The bottom portion of the waste liquid treatment device is formed by a base portion **105**.

In the waste liquid treatment device having the above-mentioned structure, a chlorine containing organic solvent which is finely dispersed in a waste liquid is separated by the solvent separation unit **61**, and chlorine containing organic solvent in the waste liquid is vaporized by the vaporization treatment unit **63**. The vaporized chlorine containing organic solvent gas is photooxidized and decomposed by the photooxidation decomposition processing unit **65**, and the resultant decomposition product gas including chlorine gas is converted to harmless salts by the after-treatment unit **67**. Accordingly, it becomes possible to decrease the amount of chlorine containing organic compounds present in treated drainage and exhaust gas, and the output of chlorine gas, which is a secondary by-product, to be within the range of emission standard values defined by the Water Pollution Control Law. Therefore, the present invention may contribute to the prevention of environmental pollution.

Also, since the device is constructed so that chlorine containing organic compounds contained in waste liquid supplied from, for example, a dry cleaning device, are adsorbed by the solvent separation unit **61**, vaporized in the vaporization treatment unit **63**, and photooxidized and decomposed in the photooxidation decomposition processing unit **65**, it becomes possible, compared to the case wherein waste liquid is directly subjected to a photooxidation decomposition process, to increase the photooxidation decomposition treatment efficiency, and hence, the time and cost required to execute the process may be reduced.

Moreover, since the separation member **72** which forms the solvent separation unit **61** is mainly formed by a porous material made of, for instance, a sintered compact of a water-repellent and/or lipophilic resin, it becomes possible to efficiently adsorb a chlorine containing organic solvent which is finely dispersed in waste liquid. This has been difficult to achieve by using the conventional techniques.

Further, according to an embodiment of the present invention, the chlorine containing organic solvent which has been adsorbed by the separation member **72** is vaporized by the gas generated by the aeration process, and the resulting gas can be discharged to the vaporized gas supply line **64** using the pressure inside the aeration vessel **70**. Accordingly, energy may be efficiently used according to the present invention. In the above-mentioned manner, the separation member **72** is regenerated without being saturated by the chlorine containing organic solvent, and it is possible to repeatedly carry out the solvent separation process.

In addition, since an air diffusion pump which may be used for a domestic water tank may be utilized as a source for supplying compressed air used for an aeration process, it becomes possible to decrease the cost required for the device.

Also, since an air diffusing member **80** comprising an air diffusing tube or an air diffusing plate may be provided at the compressed air inlet portion **78** at the inside of the aeration vessel **70**, it becomes possible to decrease the size of the bubbles generated in waste liquid during an aeration process. Accordingly, the contact time and area of the bubbles with the waste liquid may be increased, and hence, excellent aeration efficiency can be achieved.

Moreover, since a container which is long in the vertical direction is used as the aeration vessel **70**, it becomes possible to increase the contact time and area of the air with the waste liquid, and hence, the aeration efficiency may be improved and the time required for the process may be shortened.

Further, because the inside surfaces of the passage through which the vaporized gas and/or the decomposition product gas flows are coated by a polymeric material, such as a fluororesin or a polyethylene type resin, having excellent corrosion resistance properties, and chemical resistance properties, or made of such a polymeric material, they are not significantly corroded by the chlorine gas, etc.

In addition, by using the straight tube member **84***a* having an inner diameter of about 5–30 mm, and a length of about 200–800 mm in the photooxidation decomposition processing unit **65**, it becomes possible to uniformly irradiate the entire photocatalyst reaction portion **86** including the center portion thereof by the ultraviolet light from the ultraviolet light sources **88**. Accordingly, the waste liquid treatment device of the invention has an excellent photooxidation-decomposition treatment efficiency.

Also, since photocatalyst granules **85** having a particles size of about 1–20 mm are used to increase the specific surface area thereof, it becomes possible to increase the efficiency the photocatalyst granules **85** to make contact with the vaporized gas, and the light receiving efficiency of the photocatalyst granules **85**. Accordingly, the waste liquid treatment device of the invention has an excellent photooxidation-decomposition treatment efficiency.

Moreover, since a mixture of an inorganic powder, which adsorbs the chlorine containing organic gases or chlorine gases, and photocatalyst particles is used as the photocatalyst granules **85**, the chlorine containing organic gas, etc. is subjected to a photooxidation-decomposition process while adsorbed onto the photocatalyst granules **85**. Accordingly, the waste liquid treatment device of the invention has an excellent photooxidation-decomposition treatment efficiency, and undecomposed chlorine containing organic materials are not discharged to the outside of the photooxidation decomposition processing unit **65**.

Further, since the straight tube members **84***a* and the ultraviolet light sources **88** are vertically disposed, the photooxidation decomposition processing unit **65** has a vertically elongated structure. Accordingly, it becomes possible to reduce the area for installing the device of the invention.

Next, operation of the waste liquid treatment device according to another embodiment of the invention will be described with reference to FIG. **12**.

When power is supplied to the waste liquid treatment device of an embodiment of the invention (**S101**), the device is started and the following series of operations are performed under the control of the sequencer **101** in the control unit **68**.

First, the ultraviolet light sources **88** enter a standby mode (**S102**).

Then, waste liquid including a chlorine containing organic solvent is supplied to the waste liquid supply unit from a water separator of a dry cleaning device. When the supplied waste liquid reaches the upper limit and is detected by an upper limit liquid level sensor disposed in a waste liquid vessel (**S103**), the ultraviolet light sources **88** are turned on (**S104**), a waste liquid supply pump is actuated (**S105**), and the waste liquid is supplied to the solvent separation unit **61** which is disposed at the upper portion of the aeration vessel **70**. After this, part of the chlorine containing organic solvent which is dispersed in the waste liquid in a fine particle state, are adsorbed by the separation member **72** of the solvent separation unit **61**, and the waste liquid in which the rest of the chlorine containing organic solvent is dissolved, is supplied to the aeration treatment unit which is disposed at the lower portion of the aeration vessel **70**.

Then, when the level of the waste liquid in the aeration treatment unit reaches the position of the liquid level sensor **70** disposed at the outside surface of the aeration vessel **70** (**S106**), the supply of the waste liquid is stopped (**S106'**), and the air pump **81** is actuated (**S107**) to start the aeration process for the waste liquid.

At that time, as the chlorine containing organic solvent present in the waste liquid is vaporized, the chlorine containing organic solvent adsorbed by the separation member **72** is also vaporized by the air including the vaporized chlorine containing organic solvent and is supplied to the photooxidation decomposition processing unit **65**.

After that the chlorine containing organic gas which is supplied to the photooxidation decomposition processing unit **65**, is decomposed by the photocatalyst granules **85**, which are excited by the ultraviolet light, in the photocatalyst reaction portion **86** and converted into water, carbon dioxide, and chlorine gas, and supplied to the after-treatment unit **67**.

In the after-treatment unit **67**, a neutralization-reduction process is carried out by using an alkali ion solution containing sodium carbonate, sodium bicarbonate, sodium thiosulfate, etc., to convert the chlorine containing organic gas and the chlorine gas into chlorine ions which are dissolved in the solution.

Next, when the aeration process has been carried out for sufficient time to reduce the concentration of the chlorine containing organic solvent in the waste liquid to a level sufficiently below the emission standard value (about 20 minutes), the air pump **81** is stopped (**S108**), and the aeration process is terminated. After that, the electromagnetic valve **83** is opened (**S109**), and the drainage in the aeration vessel **70** is discharged into the treated drainage storage vessel of the treated drainage discharge unit which is separately provided.

When the discharge of drainage is terminated, the electromagnetic valve **83** is closed (**S110**), and the air pump **81** is actuated for five minutes (**S111**) to supply air to the aeration vessel **70** and regenerate the separation member **72**.

If the level of the waste liquid in the waste liquid vessel does not reach the position of the lower limit liquid level sensor when the regeneration of the separation member **72** is completed (**S112**), the cycle of **S105–S111** explained above is repeated. On the other hand, if the level of the waste liquid in the waste liquid vessel reaches the position of the lower limit liquid level sensor when the regeneration of the separation member **72** is completed (**S112**), the air pump **81** is actuated for one hour (**S113**) to supply air into the aeration vessel **70** and completely regenerate the separation member **72**.

After the separation member is regenerated, if the level of the waste liquid which is supplied from the water separator of the dry cleaning device, in the waste liquid vessel again reaches the position of the upper limit liquid level sensor disposed in the waste liquid vessel (**S114**), the cycle of **S105–S111** explained above is repeated. On the other hand, if the level of the waste liquid in the waste liquid vessel does not reach the position of the upper limit liquid level sensor (**S114**), the ultraviolet light sources **88** are turned off and enter the standby mode until the level of the waste liquid in the waste liquid vessel reaches the position of the upper limit liquid level sensor.

As explained above, since the waste liquid treatment processes are automated and the standby mode is introduced, it becomes possible to save electric power, to extend the life of the ultraviolet light sources **88**, and to minimize the cost treating the waste liquid.

Also, in a cleaning or dry cleaning device using the above-mentioned waste liquid treatment device, since the series of processes from the cleaning process to the waste liquid treatment process may be automated, it becomes possible to decrease the cost of the series of processes. Moreover, in the above device, the efficiency in the series of processes for decomposing the chlorine containing organic solvent in the waste liquid is excellent, and also the discharge of secondary by-products may be prevented.

As described above, according to the method for treating waste liquid of an embodiment of the invention, since the chlorine containing organic solvent dispersed in the waste liquid in a fine particle state may be readily adsorbed and removed in the solvent separation process, it becomes possible to reduce the time and cost of the waste liquid treatment process. Accordingly, the amount of chlorine containing organic compounds in drainage or in exhaust gas, or the amount of chlorine gas which is a by-product, may be readily reduced to within the emission standard values.

Also, according to the method for treating waste liquid of an embodiment of the invention, since the solvent separation member is regenerated by air including a chlorine containing organic solvent, which has been vaporized in the vaporization treatment process, or by fresh air supplied from outside, the porous materials which form the separation member may maintain their ability to treat the waste without being saturated by the chlorine containing organic solvent. Accordingly, it becomes possible to decrease the cost of the process.

Moreover, in the waste liquid treatment device according to an embodiment of the invention, since the control unit is provided, it becomes possible to automatically carry out the series of waste liquid treatment processes. Accordingly, if the waste liquid treatment device is used for a washing device, such as a cleaning device, it becomes possible to automatically start or stop the device depending on the operational situation. Therefore, it is possible to not only extend the life of the ultraviolet light sources but also to reduce the cost of the operation without wasting power.

Further, in the waste liquid treatment device according to an embodiment of the invention, since the device is downsized and a low-cost domestic pump or air-pump is utilized, the manufacturing cost of the device may be reduced. In addition, the running cost of the device may also be reduced and the maintenance of the device can be easily performed.

Also, as described above, since the solvent separators according to the embodiments of the invention are capable of continuously carrying out the introduction of waste liquid, the separation, vaporization, and discharge of the chlorine containing organic solvent, the discharge of water, and the regeneration of the porous material which constitutes the separation unit, it becomes possible to efficiently carry out the separation of the chlorine containing organic solvent.

Moreover, according to the solvent separators of the embodiments of the present invention, since the chlorine containing organic solvent is adsorbed by the porous material by utilizing the differences in wetting properties between the chlorine containing organic solvent and water, it becomes possible to adsorb and separate the chlorine containing organic solvent which is dispersed in waste liquid in a fine particle state. Moreover, the chlorine containing organic solvent, once adsorbed by the separation member, does not return to the waste liquid. Accordingly, the separation of the chlorine containing organic solvent from the water is carried out substantially completely, and water discharged from the solvent separator does not contain the chlorine containing organic solvents.

Having thus described several exemplary embodiments of the invention, it will be apparent that various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements, though not expressly described above, are nonetheless intended and implied to be within the spirit and scope of the invention. Accordingly, the invention is limited and defined only by the following claims and equivalents thereto.

What is claimed is:

1. A solvent separator, comprising:

an introduction member which introduces a mixture comprising a chlorine containing organic solvent and water;

a separation unit comprising a separation member made of a water-repellant and/or lipophilic porous material, which carries out the separation of said mixture, wherein said separation member has the form of a film, plate, tube, container, or granules;

a water drainage member through which water separated by said separation unit is discharged; and

a solvent drainage member through which the chlorine containing organic solvent separated by said separation unit is discharged.

2. A solvent separator, comprising:

an introduction member which introduces a mixture comprising a chlorine containing organic solvent and water;

a separation unit comprising a separation member made of a water-repellant and/or lipophilic porous material, which carries out the separation of said mixture;

a water drainage member through which water separated by said separation unit is discharged;

a supply member which supplies air to said separation unit to vaporize said chlorine containing organic solvent; and

an exhaust member through which the air supplied by said supply member and/or vaporized chlorine containing organic solvent is discharged.

3. A solvent separator according to claim 2, wherein said separation member has the form of a film, plate, tube, container, or granule.

4. A dry cleaning device comprising a solvent separator comprising:

an introduction member which introduces a mixture comprising a chlorine containing organic solvent and water;

a separation unit comprising a separation member made of a water-repellant and/or lipophilic porous material, which carries out the separation of said mixture;

a water drainage member through which water separated by said separation unit is discharged; and

a solvent drainage member through which the chlorine containing organic solvent separated by said separation unit is discharged.

5. A method for treating waste liquid comprising the steps of:

carrying out a solvent separation process in which a chlorine containing organic solvent present in waste liquid is separated;

carrying out a vaporization treatment process after said solvent separation process whereby chlorine containing organic solvent remaining in the waste liquid is vaporized;

carrying out a photooxidation-decomposition process in which gas vaporized from the waste liquid is subjected to a photooxidation-decomposition treatment; and

carrying out an after-treatment process in which decomposition product gas produced by the photooxidation-decomposition treatment is converted into a harmless substrate.

6. A method for treating waste liquid according to claim 5, wherein said decomposition product gas is adsorbed, absorbed, and neutralized in said after-treatment process to be converted into a harmless substance.

7. A method for treating waste liquid according to claim 5, wherein said solvent separation process is performed prior to said vaporization treatment process.

8. A method for treating waste liquid according to claim 5, wherein

the waste liquid is brought into contact with a separation member made of a water-repellant and/or lipophilic porous member so that the chlorine containing organic solvent present in the waste liquid is adsorbed by the separation member in said solvent separation process.

9. A method for treating waste liquid according to claim 8, wherein said vaporization treatment process includes a step of vaporizing the chlorine containing organic solvent adsorbed by said separation member.

10. A method for treating waste liquid according to claim 5, wherein said vaporization treatment process is performed by using an aeration method.

11. A waste liquid treatment device, comprising:

a solvent separation unit which separates chlorine containing organic solvent present in waste liquid;

a vaporization treatment unit which vaporizes a part of the chlorine containing organic solvent which was not separated by said solvent separation unit and remains in the waste liquid;

a photooxidation decomposition processing unit which photooxidizes and decomposes gas vaporized from the waste liquid by said vaporization treatment unit;

an after-treatment unit which converts decomposition product gas produced by said photooxidation-decomposition processing unit into a harmless substrate; and

a control unit including a sequencer which controls an operation of said solvent separation unit, said vaporization treatment unit, said photooxidation decomposition processing unit, and said after-treatment unit.

12. A waste liquid treatment device according to claim 11, wherein said after-treatment unit adsorbs, absorbs, and neutralizes the decomposition product gas in order to convert the decomposition product gas into a harmless substrate.

13. A cleaning device comprising the waste liquid treatment device according to claim 11.

14. A dry waning device comprising the waste liquid treatment device according to claim 11.

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